AD-A043 991 UPPER COLORADO REGION STATE-FEDERAL INTER-AGENCY GROUP F/G 8/6
UPPER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDY. APPENDIX I--ETC(U)
JUN 71

UNCLASSIFIED NL

1 OF 2
AD
A043991

Upper Colorado Region

Comprehensive Framework Study

Appendix IX
Flood Control

Upper Colorado Region State-Federal Inter-Agency Group / Pacific Southwest
Inter-Agency Committee / Water Resources Council
June 1971

This appendix was prepared by the
FLOOD CONTROL WORK GROUP
of the
UPPER COLORADO REGION STATE-FEDERAL INTERAGENCY GROUP
for the
PACIFIC SOUTHWEST INTERAGENCY COMMITTEE
WATER RESOURCES COUNCIL

WORK GROUP MEMBERS

Name	Agency
Amos W. Hoggard - Chairman	Corps of Engineers
Richard J. Vasquez - Chairman (1970)	Corps of Engineers
Ray D. Eicher	Bureau of Indian Affairs
S. Gene Day	Bureau of Land Management
Don H. Barnett	Bureau of Reclamation
Wendell M. Doty, Jr.	Forest Service
H. Grant Seaman (Alt.)	Forest Service
John D. Hedlund	Soil Conservation Service
R. L. Raetz	National Weather Service
Phillip C. Briggs	State of Arizona
Laren D. Morrill	State of Colorado
David P. Hale	State of New Mexico
Paul L. Gillette	State of Utah
Floyd A. Bishop	State of Wyoming
Peter J. Hutchinson (Alt.)	State of Wyoming

Other contributors:

William E. Anderson, Soil Conservation Service
Ivan F. Wymore, Soil Conservation Service
George W. Bjerke, Soil Conservation Service
Elven S. McDonough, National Weather Service
Clifford Boyce, Bureau of Reclamation
R. E. Farrer, State of Arizona
Roland Palmer, State of Utah
Delbert L. Boyer, State of Wyoming
Cecil B. Jacobson, Upper Colorado River Commission

The Grand Junction and Telluride, Colorado, flood damage photos used in the appendix were provided courtesy of the Daily Sentinel, Grand Junction, Colorado.

6 UPPER COLORADO REGION

COMPREHENSIVE FRAMEWORK STUDY

APPENDIX IX

FLOOD CONTROL

11 June 1971

12 110p.

This report of the Upper Colorado Region State-Federal Interagency Group was prepared at field level and presents a framework program for the development and management of the water and related land resources of the Upper Colorado Region. This report is subject to review by the interested federal agencies at the departmental level, by the Governors of the affected states, and by the Water Resources Council prior to its transmittal to the Congress for its consideration.

410370

LIST OF DOCUMENTS
COMPREHENSIVE FRAMEWORK STUDIES

MAIN REPORT

Appendix I	History of Study
Appendix II	The Region
Appendix III	Legal and Institutional Environments
Appendix IV	Economic Base and Projections
Appendix V	Water Resources
Appendix VI	Land Resources and Use
Appendix VII	Mineral Resources
Appendix VIII	Watershed Management
Appendix IX	Flood Control
Appendix X	Irrigation and Drainage
Appendix XI	Municipal and Industrial Water
Appendix XII	Recreation
Appendix XIII	Fish and Wildlife
Appendix XIV	Electric Power
Appendix XV	Water Quality, Pollution Control and Health Factors
Appendix XVI	Shoreline Protection and Development (not applicable to Upper Colorado Region)
Appendix XVII	Navigation (not applicable to Upper Colorado Region)
Appendix XVIII	General Program and Alternatives


UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY
25 0 25 50 75 100 125 150 MILES
HYDROLOGIC
SUBREGIONS
1. Green River
2. Upper Main Stem
3. San Juan - Colorado
WYOMING
UTAH
COLORADO
ARIZONA
NEW
MEXICO
1
2
3
SUBLETTE
Pinedale
LINCOLN
Kemmerer
SWEETWATER
Green River
Rock Springs
UINTA
Flaming Gorge Reservoir
SUMMIT
Manila
DAGGETT
CARBON
MOFFAT
Craig
ROUTT
Steamboat Springs
GRAND
Hot Sulphur Springs
DUCHESNE
Duchesne
Vernal
Roosevelt
UINTAH
RIO BLANCO
Meeker
WASATCH
CARBON
Price
GARFIELD
EAGLE
Eagle
Glenwood Springs
Breckenridge
SUMMIT
PITKIN
Aspen
Castle Dale
EMERY
Green River
GRAND
Grand Junction
MESA
DELTA
Delta
GUNNISON
Gunnison
Blue Mesa Reservoir
Moab
Montrose
MONTROSE
SEVIER
SANPETE
WAYNE
GARFIELD
OURAY
Ouray
SAN MIGUEL
Telluride
Lake City
SAGUACHE
Monticello
DOLORES
Silverton
SAN JUAN
KANE
Lake Powell
SAN JUAN
Bluff
MONTEZUMA
Cortez
LA PLATA
Durango
MINERAL
Pagosa Springs
ARCHULETA
Navajo Reservoir
Page
Lees Ferry
COCONINO
NAVAJO
Kayenta
Aztec
Farmington
SAN JUAN
RIO ARRIBA
APACHE
SANDOVAL
McKINLEY
GREEN
RIVER
COLORADO
Fontenelle Reservoir
GREAT BASIN
UPPER COLORADO
LOWER COLORADO
PACIFIC OCEAN
CALIFORNIA
NEVADA
ARIZONA
MEXICO
113° 112° 111° 110° 109° 108° 107° 106°
43° 42° 41° 40° 39° 38° 37° 36° 35°

SUMMARY

The Flood Control Work Group finds that flood problems exist in the Upper Colorado Region and that substantial flood damage can be expected in the future unless adequate flood damage reduction programs are implemented. It is estimated that the total average annual flood damage in 1965 was $2.8 million, and in the absence of additional damage reduction measures the flood damage will increase to $4.2 million by 1980, $6.8 million by 2000, and $10.6 million by 2020.

The future flood damage reduction program consists of non-structural flood plain management measures, utilization of proposed multiple-purpose reservoirs for flood control storage, and construction of other structural flood control works where required. Flood control storage in future multiple-purpose reservoirs and small flood retarding structures would amount to 2,300,000 acre-feet. Other structural measures would include construction of 9 miles of levees and improvement in the flow capacities of 11 miles of channels. Non-structural measures would include improved flood forecasting, dissemination of flood hazard information, flood plain zoning, and other measures by local authorities. Flood damages would also be reduced by land treatment on 7,112,000 acres under watershed management programs.

It is estimated the program presented would reduce the projected average annual flood damage to $3.3 million by 1980, $3.4 million by 2000, and $3.8 million by 2020. The damage projections are based on a modification of the OBERS baseline projections referred to as the Regional Interpretation of OBERS (RI-OBERS). OBERS baseline projections, three State Alternative development levels, and their effect on the flood control program are discussed in Supplement A.

The incremental installation costs of the program are estimated at $14.8 million, $29.9 million, and $15.1 million in the 1966-1980, 1981-2000, and 2001-2020 time frames, respectively. Except for the small detention type reservoirs and levee and channel improvements, these costs do not include the portion of total costs of watershed land treatment and water control facilities related to flood control in watershed projects. Such costs are included in the overall watershed program costs in Appendix VIII - Watershed Management.

The future flood control plan contained in this appendix is a preliminary or reconnaissance level plan which indicates the seriousness of the flood problem and furnishes possible solutions to these problems. These problems and solutions should be studied in detail followed by timely implementation of appropriate flood damage reduction measures.

CONTENTS

CONTENTS (Continued)

NARRATIVE TABLES

TABLES FOR EACH SUBREGION

CONTENTS (Continued)

FIGURES

MAPS

CONTENTS (Continued)

PHOTOGRAPHS

UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY
APPENDIX IX - FLOOD CONTROL

PART I

INTRODUCTION

Purpose and Scope

The purpose of this appendix is to present an assessment of the present and future flood problems in the Upper Colorado Region, determine future flood control needs, and outline a comprehensive program to satisfy these needs. The material includes a description of the region, a history of floods, a description of existing flood control measures and their accomplishments, an evaluation of remaining flood problems and future needs, and a description of a possible future flood control program required in 1980, 2000, and 2020 to meet these needs. The studies are limited to the Colorado River Basin upstream from Lee Ferry, Arizona, and the Great Divide Closed Basin in Wyoming.

The principal source of data used herein are prior studies and reports made by Federal and State agencies. These data were updated to base year (1965) prices and conditions of development. Where data were incomplete or missing, basic data were derived by comparison with data known on similar stream basins. Values of flood damage derived for the base year were projected to target years by use of development factors based on economic growth expected in the flood plains in the absence of future flood damage reduction measures.

Future conditions were based upon a field adjustment of the Department of Commerce Office of Business Economics' (OBE) projections of population, personal income, and employment, and the Department of Agriculture Economic Research Service's (ERS) projections of agricultural production. Based on these estimates flood damages were projected to the target years of 1980, 2000, and 2020. This modification of the OBE-ERS baseline projections is referred to as the Regional Interpretation of OBERS (RI-OBERS). Both sets of projections are presented in detail in Appendix IV - Economic Base and Projections. Alternative levels of economic development projections based upon the use of 6.5 and 8.16 million acre-feet of water use have been developed as well as a third alternative based on water supply available at the site of use. These alternatives and the effect on the flood damage reduction program are discussed in Supplement A attached to this report. Estimates of future damages were considered to be a measure of the needs for future flood damage reduction programs. In the development of a plan

to reduce future flood damages, consideration was given to controlled land use in flood plains and other non-structural flood plain management practices; to construction of reservoirs and levees, and channel improvements where necessary to protect existing facilities and those projected to be developed in flood plains in the future; and to watershed management practices where appropriate. Alternatives were selected for the plan on the basis of projected land use needs, feasibility of non-structural measures, necessity of structural improvements, and economy of alternatives. The results of the studies are presented in the remainder of the appendix and are summarized in the subregional tables at the end of this report.

Objectives

The planning objectives for framework studies are to give consideration to the timely development and management of water and related land resources, and to the preservation of resources in appropriate instances to insure they will be available for their best use as needed, with the well-being of all the people as the overriding consideration. Flood damage reduction is an essential part of this planning process, since it contributes to the well-being of people by preventing loss of life, human suffering, damage to property, and loss of goods and services. Complete flood protection is an unrealistic goal because the cost of protection in comparison to the reduction in damages and other uses of land and water resources may preclude flood protection; however, flood protection, to reduce excessive damages and be consistent with environmental considerations and other resource uses, should be provided.

In consonance with these general guidelines, the objectives of the flood damage reduction program in this report are to provide flood protection from at least a once-in-10-year flood for agricultural areas, and protection from the once-in-100-year flood up to the Standard Project Flood for urban areas.

Relationship to Other Parts of Report

The Upper Colorado Region Framework Study report is composed of a main report and 16 appendixes. Appendixes I, II, and III, "History of Study," "The Region," and "Legal and Institutional Environments," furnishes background material. Appendixes IV, V, VI, and VII, "Economic Base and Projections," "Water Resources," "Land Resources and Use," and "Mineral Resources," include basic information that is utilized in

the other appendixes. Appendixes VIII-XV, "Watershed Management," "Flood Control," "Irrigation and Drainage," "Municipal and Industrial Water," "Recreation," "Fish and Wildlife," "Electric Power," and "Water Quality, Pollution Control, and Health Factors," are the functional appendixes of the report, each dealing with a particular recognized phase of water and related land development, use, or management. Appendixes XVI and XVII, "Shoreline Protection and Development" and "Navigation," are not applicable to this region. Appendix XVIII, "General Program and Alternatives," analyzes the resources, demands, or goals of the region and presents a framework plan and alternative plans of how demands or goals can best be met. The main report is a condensation of the supporting appendixes and will include the framework plan, conclusions, and recommendations.

Solutions to flood problems have an impact on other water and land resources problems. For example, future reservoirs used for flood control, except for small detention reservoirs in watershed areas, will also be used for one or more of the following purposes: irrigation, municipal and industrial water supply, hydroelectric power production, outdoor recreation, fish and wildlife conservation, water quality control, and possibly other purposes. Non-structural flood plain management programs are primarily for prevention of flood damage, yet they provide excellent opportunities to restore and enhance natural beauty and to develop recreational facilities, including parks, golf courses, playgrounds, and picnic areas. Facilities provided under watershed treatment practices reduce rates of flood runoff, increase timber and range production, provide fire and sediment control, provide opportunities for outdoor recreation, and increase water yield for better crop production. Thus, solutions of flood problems in this appendix are closely related to solutions of other water and land resource problems covered in other appendixes.

Description of the Region

The Upper Colorado Region, as shown on Plate 1, is that area drained by the Colorado River upstream from Lee Ferry, Arizona, and the Great Divide Closed Basin in south-central Wyoming. The region is located between the Continental Divide and the Wasatch Mountain Range with land areas in Arizona, Colorado, New Mexico, Utah, and Wyoming totalling 113,496 square miles, including 3,916 square miles in the Great Divide Closed Basin. The region is characterized by rugged mountains and narrow valleys cut by the Colorado River and its tributaries. Elevations range from about 14,000 feet on the highest mountain peaks to about 3,100 feet at the level of the Colorado River at Lee Ferry.

The Colorado River rises on the west side of the Continental Divide in west-central Colorado, meanders southwest 640 miles through Colorado and Utah to Lee Ferry in Arizona. The Green River, its principal tributary, rises in the mountains of western Wyoming and flows in a southerly direction 730 miles to its junction with the Colorado River in southeastern Utah, at a location 220 miles above Lee Ferry. Other large tributaries of the Colorado River are the Gunnison, Dolores, and San Juan Rivers. The principal streams and their tributaries are in some locations deeply entrenched in the rugged plateau country which comprises most of the region.

The climate is arid to semiarid except in the high altitudes in the headwater areas, where precipitation is moderately heavy. Wide ranges in the climate are caused by differences in altitude, latitude, and topography. In general, the climate is associated with Pacific Ocean air masses which move inland from the west, bringing most of the region's precipitation. Seasonal influences include cyclonic thunderstorms that enter into the southern portion of the region from the Gulf of Mexico, and Canadian arctic air occasionally extends into the northern portion of the region during the winter months.

Temperatures vary widely due to seasonal and diurnal effects and differences in elevation. Extremes of temperatures range from -60° F. at Taylor Park, Colorado, to 115° F. at Lee Ferry, Arizona. At most climatological stations, mean monthly temperatures are lowest in January and highest in July and have about a 50° F. difference. Average annual temperatures vary from below freezing at elevations above 10,000 feet to about 50° F. in the river valleys below elevation 5,000 feet. In general, the northern portion of the region is characterized by short, warm summers and long, cold winters, and the southern portion by relatively longer summers and more moderate winters.

The Upper Colorado Region is somewhat isolated from major sources of moisture and air masses have to cross numerous high mountain ranges and travel great distances on their way to the region. Thus, precipitation is low except in the high mountain areas. The average annual precipitation ranges from less than 6 inches in the lowest valleys to 50 inches or more in the highest elevations. For most of the region the greatest amount of precipitation occurs as snow during winter and spring. However, in the southern portion, maximum monthly precipitation often occurs in July, August, and September as the result of summer thunderstorms.

An average of about 95 million acre-feet of water annually is provided by precipitation in the region. About 80 million acre-feet

of the total is returned to the atmosphere by evapotranspiration. The remaining 15 million acre-feet is the source of streamflow. Some of the total supply, possibly 100,000 to 200,000 acre-feet annually, recharges the ground water and is later withdrawn primarily for municipal and industrial use. Streams originate in the forested watershed areas and are fed primarily by melting snow in late spring and early summer. Normally, high rates of runoff subside by late July to near base or minimum flow, which includes spring-fed headwater contribution, return flow from irrigation, and streambank storage. A small amount of runoff originates at the lower altitudes from infrequent storms. Approximately 75 percent of the runoff in the region is produced on about 14,200 square miles or 13 percent of the total drainage area. Runoff in the Great Divide Basin portion of the region is small and intermittent, and is used locally.

The population of the region in 1965 was 337,000. The annual rate of increase in population since 1940 was about 1 percent. For the same period, the national rate of increase was 1.67 percent and the rate of increase for the 11 western states was 3.34 percent. The 1965 population density was about 3 persons per square mile of area. The national average was about 64 persons per square mile. There are no large metropolitan centers. The largest cities and their populations in 1965 are Grand Junction, Colorado (22,400), Farmington, New Mexico (21,000), Durango, Colorado (11,200), and Rock Springs, Wyoming (10,300). All the other communities had populations of less than 10,000. Only about 37 percent of the region's population live in urban areas with more than 2,500 inhabitants.

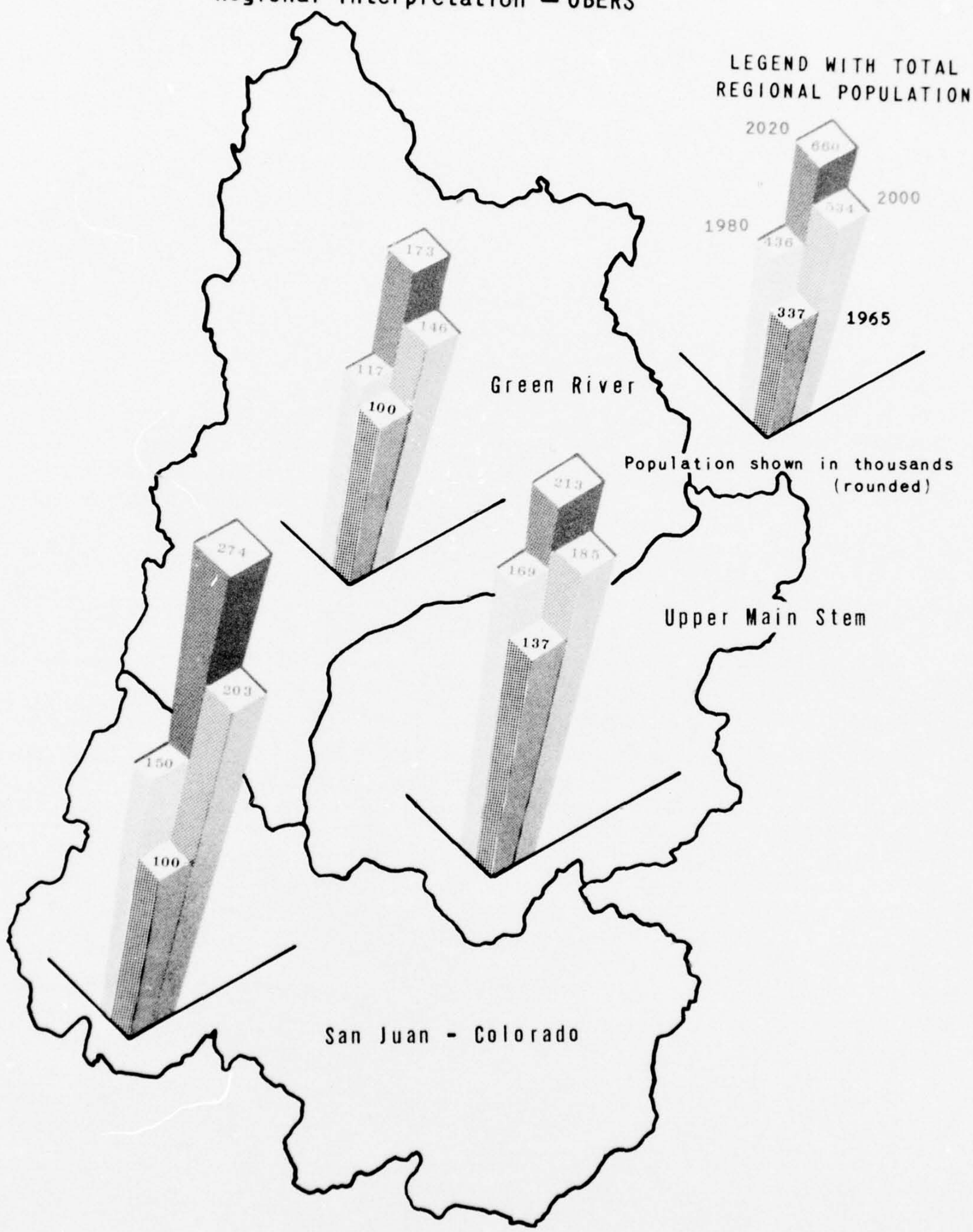
Industries that provide opportunities for employment are the services, agriculture, forest products, mining, and the manufacturing of food and kindred products. Tourism is important to the economy since several national forests, parks, and monuments in the region attract vacationers from throughout the nation. The region is served by two transcontinental railroads and a good highway network.

The Upper Colorado Region is divided into three subregions for framework study purposes, as indicated on the frontispiece map and Plate 1. The subregions and their areas are listed in the following tabulation.

Subregion	Area in sq. mi.
Green River	48,660
Upper Main Stem	26,192
San Juan-Colorado	38,644
Regional total	113,496

The population projections were based on political (county) boundaries. The hydrologic (drainage) boundaries seldom conform to the county lines; however, for the purpose of this study, the projections are considered to be quite close and representative of the hydrologic area populations. The 1965 and future populations based on the Regional Interpretation of OBERS projections are shown in the figure following this page (excluding the portion of the region in Arizona).

Projected Population Growth
Upper Colorado Region
Regional Interpretation — OBERS



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

PROJECTED POPULATION GROWTH

APPENDIX IX

PART II

HISTORY OF FLOODING

Flooding along the flood plains of major streams in the Upper Colorado Region is almost always the result of rapid snowmelt in late spring and early summer. These floods often are augmented by rain. In the southern portion of the region general rainstorms occasionally produce overbank flows. Intense summer storms are a frequent occurrence throughout the region. These storms produce high peaks and small volumes of runoff. They often cause heavy damage to local areas, and the aggregate damage from this type of summer storm is a large portion of the total average annual flood damage in the region.

Many floods have occurred in the region; however, damages caused by most of these floods were not recorded due primarily to the limited number of people affected in the sparsely settled areas which were flooded. On a basin-wide scale the largest recent flood in the region occurred in June-July 1957 when most of the major streams overflowed. Other years in which widespread flooding occurred were 1911, 1917, 1921, 1937, and 1952. Flood damage in Grand Junction, Colorado, from a flood on Indian Wash in June 1958 is shown in the upper photo following page 8. Possibly the most disastrous flood of record occurred on Sheep Creek, a tributary of Green River, in June 1965, as a result of heavy rain on snow. Seven lives were lost in this flood which also destroyed roads, bridges, campgrounds, and other developments with total damages estimated at about $800,000. On 31 July 1969 a cloudburst flood (see lower photo following page 8) on a small tributary to the San Miguel River located in the Upper Main Stem Subregion, damaged the town of Telluride, Colorado (1969 population 900). The flood destroyed 5 homes, damaged 20 others, and inflicted losses to private and public properties. The damage was estimated at $150,000. Data concerning past floods, for which historical flood damage data are available from field surveys, are indicated in Table A, page 8.

Table A
HISTORICAL FLOODS

Subregion	Stream	Date of flood	Flood damage at time of flood in $1,000
Green River	Price River	Jun 1917	380
	Bitter Creek	Jul 1937	258
	Fortification Creek	Mar 1947	37
	Duchesne River	Jun 1952	103
	Yampa River	Jun 1952	178
	Green River	Jun 1957	155
	Sheep Creek	Jun 1965	802
	White River	Mar 1966	88
Upper Main Stem	Mill & Pack Creeks	Aug 1935	62
	Colorado River	Jun 1952	69
	Colorado River	Jun 1957	192
	N. Fork Gunnison R.	Jun 1957	87
	Gunnison River	Jun 1957	239
	Dolores River	Apr 1958	229
	Uncompahgre River	Jun 1958	65
	Cornet Creek	Jul 1969	150
San Juan-Coloado	San Juan River	Oct 1911	360
	Animas River	Jun 1927	166
	Animas River	May 1941	43
	Aztec Arroyos	Aug 1965	92
	Animas River	Sep 1970	717

Detailed information concerning some of the above listed floods and several other floods of record is given in Table 1.

Flooding of Residential area in Grand Junction, Colorado from Indian Wash during flood of 6 June 1958.

Flood damage at Telluride, Colorado from 31 July 1969 cloudburst storm on Cornet Creek, a San Miguel River tributary.

PART III

PRESENT STATUS OF FLOOD CONTROL MEASURES

Flood damage reduction and prevention is accomplished by structural measures such as flood control reservoirs, floodwater retarding structures, and levees and channels; and non-structural measures such as land treatment, flood forecasting, and non-structural flood plain management measures such as zoning and building regulations. Flood control measures in operation in 1965 are discussed below.

Flood Forecasting

Peak flow and flood forecasts are issued to alert urban and agricultural areas of impending flood situations and provide them the opportunity for instituting emergency measures to minimize damages. Emergency measures may include evacuation of persons, livestock, movable property, and preparation of temporary protective structures.

Types of river and flood forecasts that have proven necessary are summarized as follows:

a. Snowmelt runoff from an above normal snowpack. The greatest runoff potential is from heavy snow cover at intermediate elevations during periods of unseasonally high temperatures followed by rain.

b. Runoff from heavy rain on a melting snowpack, usually late in spring. The flood potential increases as the rain becomes warmer at upper levels.

c. Runoff from winter rain, usually on frozen ground and with an existing snow cover on lower and intermediate elevation valley floors. This is an infrequent event in the region.

d. Forecasts of flash floods due to summer cloudburst storms are based primarily on quantitative precipitation forecasts from radar echoes and precipitation reports.

Long-range runoff volume forecasts, from which approximate snowmelt peaks and high water flows can be projected, are prepared and published in the "Water Supply Outlook for the Western United States" by the National Weather Service (National Oceanic and Atmospheric Administration)

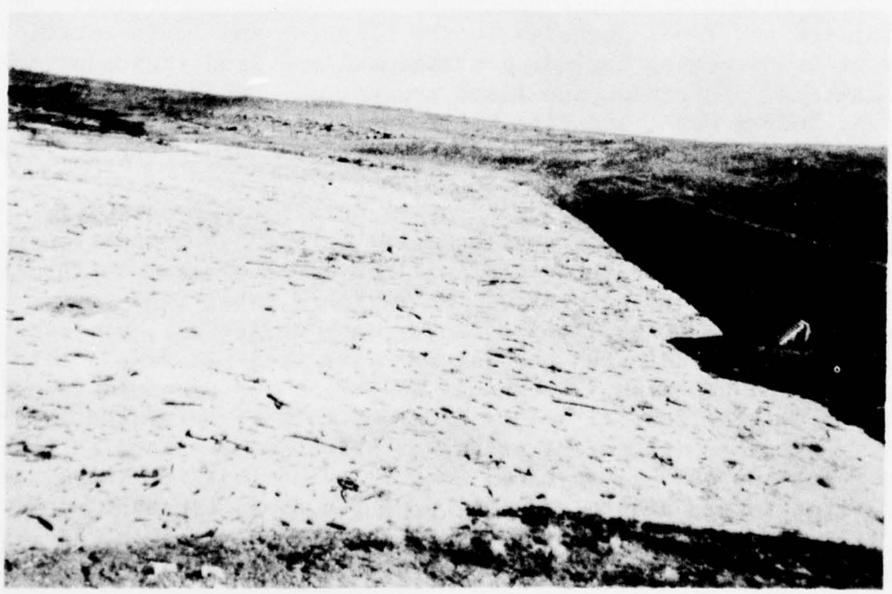
and for each state in the "Water Supply Outlook" by the Soil Conservation Service. These publications are issued as of the first of January and are updated monthly through the first of May. Information used in making forecasts are furnished by Federal, State, local, and private organizations who have access to precipitation, snow course, and river stage data. Agencies with operational responsibilities for dams and reservoirs use runoff and flood forecasts, together with information developed in their respective agencies, to determine flood routings through reservoirs so that downstream damages are held to a minimum.

Flood Control Reservoirs

There are 110 reservoirs with 1,000 acre-feet or more of storage capacity in operation in the Upper Colorado Region. There are also numerous smaller reservoirs and stock watering ponds which provide sediment storage and erosion control and may retard peak flows in small local areas. Some of the small reservoirs, constructed by private interests several decades ago, may be inadequate during large floods causing additional damage in small localized areas if overtopped; however, the dams are on small stream courses in thinly populated areas and do not pose a serious threat under present or foreseeable conditions. The combined total storage capacity of the larger reservoirs is about 36,000,000 acre-feet, including Lake Powell (Glen Canyon Dam) with a capacity of 27,000,000 acre-feet. Lake Powell is located at the downstream end of the region and has no measurable effect on flood problems in the region. If Lake Powell is excluded from the regional total there would remain about 9,000,000 acre-feet of storage that reduces flood peaks and flood damage, most of which is not operated specifically for flood control. This total storage capacity also includes dead or inactive storage. Flaming Gorge Reservoir (capacity 3,789,000 acre-feet) on Green River, Lake Granby (capacity 540,000 acre-feet) on Colorado River, Strawberry Reservoir (capacity 258,000 acre-feet) on Strawberry River, and Taylor Park Reservoir (capacity 106,000 acre-feet) on Taylor River are examples of large storage units in the region that are not operated for flood control, yet they reduce the peaks of most floods by substantial amounts. Data concerning current (1965) major multiple-purpose reservoirs in the region that are specifically operated for flood control on a flood forecast basis and watershed reservoirs operated primarily for flood control are listed in the following tabulation and shown on Plate 1. (Blue Mesa Reservoir which began filling in 1965 and Morrow Point Reservoir completed in 1967 currently provide flood control on Gunnison River.)

Subregion and State	Reservoir	Stream	Max. flood control storage capacity (1,000 ac.-ft.)	Drainage area controlled (square miles)
Upper Main	Paonia	Muddy Creek	17.0	250
Stem	Indian Wash	Indian Wash	1.0	15
(Colorado)	Roatcap	Roatcap Wash	1.0	17
Subregion totals			19.0	282
San Juan-	Vallecito	Los Pinos River	125.9	270
Colorado	Lemon	Florida River	39.0	78
(Colorado)	Pine River	Pine River	0.1	3
(New Mexico)	Navajo	San Juan River	1,036.0	3,230
Subregion totals			1,201.0	3,581
Region totals			1,220.0	3,863

Roatcap Wash Reservoir is shown in the photo below. The reservoir was partially filled with water and floating debris during a cloudburst flood on 20 July 1969.



Roatcap--a flood detention reservoir on Roatcap Wash, Colorado.

Two existing multiple-purpose reservoirs, Navajo and Vallecito, with storage operated for flood control on a forecast basis, are shown in the photos following this page.

Levees and Channels

There were no permanent type levee and channel projects in the Upper Colorado Region in 1965. Emergency work had been accomplished under Federal authorities at several locations in anticipation of floodflows and to restore channels destroyed by floods. Such work consisted of bank protection, snagging and clearing, and realignment of channels. The total cost of emergency work under Federal authority in the region through 1965 was $275,000. Locations where most of the work was accomplished are White River near Bonanza, Utah; Duchesne and Strawberry Rivers at Duchesne, Utah; Ashley Creek near Vernal, Utah; Dolores River at Dolores and Rico, Colorado; and San Juan River at Bluff, Utah. Local interests have expended considerable time and funds to rebuild damaged irrigation facilities, local roads, and other improvements damaged by flood, but specific data on such repairs are not available.

Watershed Management Programs

Under authority of the Congress, the Federal Government cooperates with states and local agencies in the planning and implementation of works of improvement, including structural and land treatment measures, for watershed protection and flood prevention. Under this authority, Roatcap, Indian Wash, and Pine River Reservoirs listed in the tabulation on page 11 were constructed and placed in operation prior to 1965.

The Federal land managing agencies have the responsibility under authorized watershed management programs to provide protection for the soil and vegetal cover on over 43 million acres of land in the region. This area is about 60 percent of the region's total land area. The remaining land in state, Indian trust, many individual, and corporate holdings has a coordinated program for watershed management with multiple objectives and benefits. Technical assistance is provided to private owners by several federal agency programs to meet watershed treatment needs. Watershed management programs, which are designed to benefit other functions as well as flood control, contribute to increasing local water intake and to reducing peak flows and sediment yield to downstream reaches. Detention, check and drop structures, diversion dams, and dikes are structural components of watershed management program.

Navajo - A multipurpose reservoir on San Juan River in New Mexico.

Vallecito - A multipurpose reservoir on Los Pinos (Pine) River in Colorado.

These structures in combination with treatment such as brush and weed control, fire control, watershed tillage, and revegetation reduce peak runoff, erosion, and sediment yield. About 9.0 million acres of land were treated for reduction of erosion, sediment, and storm runoff through 1965. Selected existing and future watershed treatment areas are shown on Plate 1. The existing treated acreages are shown by subregion and state in the following tabulation.

Subregion	State	Existing Watershed Treatment: Private	Existing Watershed Treatment: Federal
		1,000 acres	1,000 acres
Green River	Colorado	1,887	80
	Utah	2,352	156
	Wyoming	1,100	127
Subtotal		5,339	363
Upper Main Stem	Colorado	1,257	381
	Utah	90	89
Subtotal		1,347	470
San Juan-Colorado	Arizona	97	4
	Colorado	667	26
	New Mexico	473	138
	Utah	243	125
Subtotal		1,480	293
Region total		8,166	1,126

Typical examples of watershed practices are shown in the four photos following page 14. Additional discussion and tabulations of existing watershed protection measures are given in Appendix VIII, Watershed Management.

Accomplishments of Existing Flood Control Program

The accomplishments of existing flood control programs, which have reduced flood peaks and damages on the particular streams they protect are discussed in the following paragraphs.

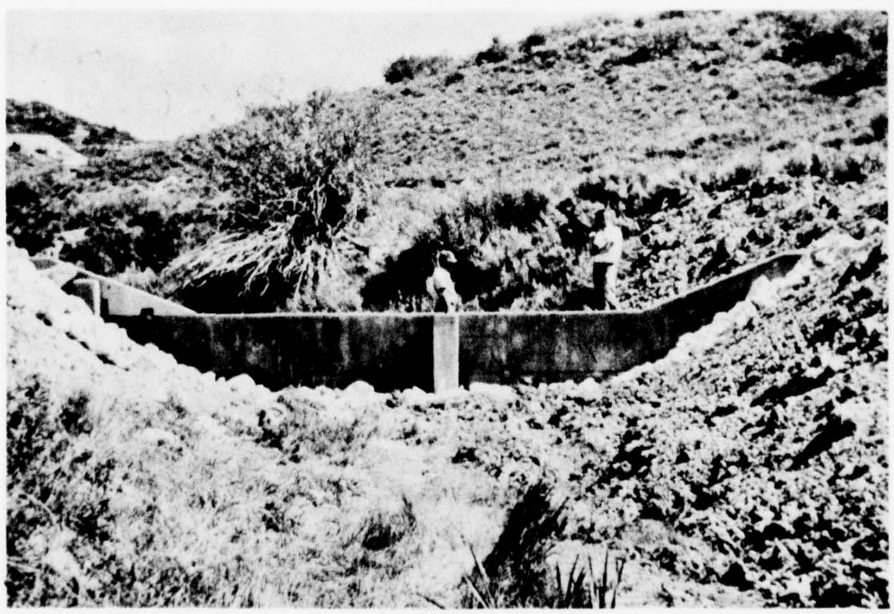
PART III PRESENT STATUS OF FLOOD CONTROL MEASURES

The present system of river forecasts provide Federal, state, and local authorities with information concerning runoff volumes and peak flows from snowmelt and general rain floods. This information is used in the operation of existing reservoirs with designated flood space to reduce peak outflow and to control floods to downstream capacities, insofar as possible. Utilization of forecasts for operation of reservoirs with flood control space has been effective in reducing flood peaks and damages and perhaps prevented the loss of life. Through the use of radar, conditions favorable to the summer cloudburst type storm are observed and the information disseminated. Due to incomplete radar coverage in this sparsely settled area the predictions of cloudburst type storms are given for general areas rather than specific locations. Accordingly, at this time, flash flooding on any particular stream cannot be forecast sufficiently in advance to allow for corrective or preventive actions to avoid damage.

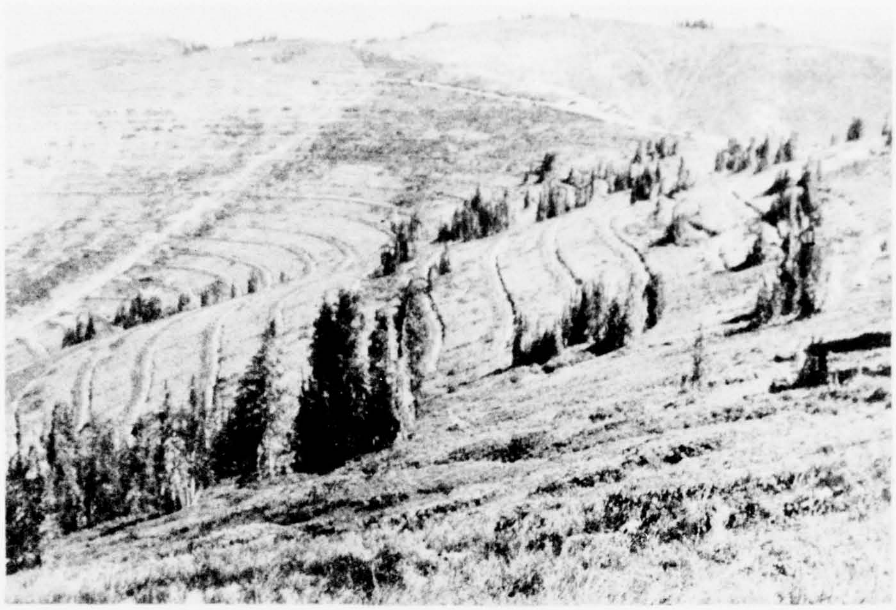
About 1,217,900 acre-feet of reservoir capacity has been designated for flood control use on a flood forecast basis in existing multiple-purpose reservoirs and a total of about 2,100 acre-feet of flood storage exists in three watershed reservoirs in the region. Most of the multiple-use capacity (1,036,000 acre-feet) is in Navajo Reservoir on San Juan River. Several of the major reservoirs in this category are identified in the tabulation on page 11. In addition to the dedicated flood control storage, there is nearly 8,000,000 acre-feet of storage in the region which is not operated for flood control, but does provide incidental flood damage reduction.

It has been noted from past experience that the existing reservoirs have helped to reduce flood peaks and damage; however, they have not been tested by large floods, and specific data are not available concerning their full effectiveness to reduce peak flows, areas subject to flooding, and flood damage. Estimates were made of the amount of damage that would have been prevented by several of the reservoirs had they been in operation during selected historical floods. These estimates are indicated as follows:

Rock check dam for control of gully erosion in watershed areas.



Prestressed concrete check dam for control of gully erosion in watershed areas.



Terracing to reduce sediment yield and runoff on steep mountain slopes.

Trenching and furrowing on the National Forest to control sediment movement and runoff.

Subregion and State	Reservoir	Date of flood	Estimated reduction in flood damage credited to reservoir (1965 prices)
Upper Main Stem (Colorado)	Paonia	4 Jun 1957	$ 17,000
	Indian Wash	6 Jun 1958	22,000
San Juan-Colorado (Colorado) (New Mexico)	Vallecito Lemon Navajo	5 Oct 1911	1,550,000

Studies indicate the existing multiple-purpose reservoirs will reduce floodflows on the streams they protect to bankful capacity for floods expected to occur more often than once in about 20 years on the average and will have some effect on flows expected in the once in 50-75 year frequency range. Flood damage prevented by these reservoirs ranges from about 30 to 50 percent of the average annual damage expected without the reservoirs. The small watershed reservoirs were designed to reduce the 100-year floodflow to bankful capacities at the reservoir sites and prevent about 80 percent of the downstream damage on the individual streams. An exception is the Pine River Reservoir which was designed to control the 25-year flood.

There were no permanent type levee and channel works in the region in 1965. The limited number of emergency type channel improvements provided by Federal agencies and local interests are considered to be temporary and no evaluations of their effects on floods were considered.

Watershed treatment has been applied to about 9.3 million acres, which is 12.9 percent of the total land area in the region. This work is effective in reducing flood threats to local areas, but due to the small area treated, the overall effect on the region's flood problems is minor. Much additional watershed treatment work is needed. There are many watershed locations where land treatment is not feasible or desirable. Scenic areas will be retained in their natural untreated condition.

PART IV

FLOOD PROBLEMS

The area subject to flood damage in the Upper Colorado Region is only a small percentage of the total area. Many streams are incised in some reaches with narrow flood plains where economic development is not practical and where flood corrective or preventive measures are not needed. In other stream reaches the flood plains are broader, encompassing all or a portion of wide mountain valleys where agricultural or urban development has occurred. In these flood plains, and in others where new economic development is expected, reduction of future flood damage is needed either by structural improvements such as reservoirs, levees, or channel works or by non-structural measures as discussed in Part VI, Measures Required to Satisfy Future Needs.

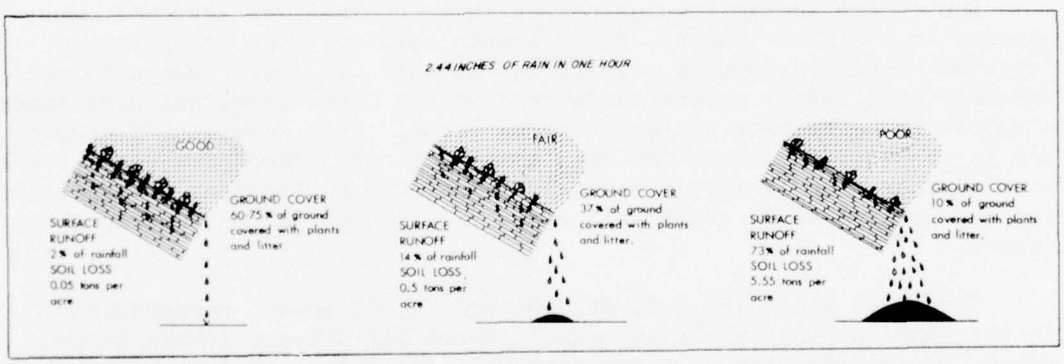
Due to the sparse population and lack of extensive economic developments in the flood plains, flood losses have not been extensive or retarded economic growth a significant amount. In recent years there has been substantial growth in several of the urban areas and more intensive use is being made of agricultural areas. This accelerated growth has increased land values and developments so that flood damage is becoming more serious than it was in the past. Based on projections of population increase and economic growth the trend is expected to continue in the future.

There are about 100,000, 50,000, and 70,000 acres, respectively, in the flood plains of the principal rivers and streams in the Green River, Upper Main Stem, and San Juan-Colorado Subregions. Streambank overflow and damage along these larger rivers and streams are caused primarily by rapid snowmelt in the spring and early summer and by an occasional winter rain. Floods on the small watershed streams result from snowmelt, winter rain, and intense summer storms. Also, ice conditions often block flow in many of the streams in the region and causes water to spread over adjacent areas. An example of ice conditions on the Gunnison River in December 1968 is shown in the upper photo following page 18. This particular condition resulted in considerable damage to summer homes and recreation areas along the stream. Other types of damage, including damage to irrigation facilities, bridges, roads, harvested hay, and farm buildings, are also caused by ice. Snowmelt and rain floods produce damage by inundating property, eroding lands, depositing silt on crops and by destroying irrigation, communication, utility, and transportation systems. The lower photo following page 18

shows an alfalfa field covered with debris resulting from a cloudburst flood occurring August 1960 on Roatcap Wash, Upper Main Stem Subregion. Floods also damage campgrounds and recreation and wildlife facilities in addition to other types of property damage mentioned above.

The intense summer storms are of short duration and produce high peak flows, low volumes of runoff, and large local damage. The size of the peak flow, volume of runoff, and amount of sediment produced by a given storm is affected by total precipitation, intensity of precipitation, topography, type of soil, and type and condition of ground cover upon which the rain falls.

The following sketches indicate the percent of runoff and soil loss on an experimental plot with all factors constant except ground cover. Although the results may not have general application, they do indicate that runoff and erosion increase when vegetation is removed from watersheds and where natural ground cover in built-over areas is replaced with pavement and roof surfaces.



The cloudburst type flood is difficult to control. Methods that have been used include a combination of land management and treatment and small water control structures.

Urban centers in the region that have experienced flood damage and are expected to experience damage in the future are listed in the tabulation on page 19.

Ice conditions on Gunnison River above Blue Mesa Reservoir in December 1968. Typical of winter conditions on many streams in the region.

Alfalfa field covered with debris from cloudburst flood on Roatcap Wash in August 1960.

Subregion	Urban centers with flood problems	Stream
Green River	Rock Springs, Wyoming	Bitter Creek
	Craig, Colorado	Fortification Creek
	Steamboat Springs, Colorado	Yampa River
	Duchesne, Utah	Duchesne River
	Vernal-Jensen, Utah	Ashley Creek
	Price-Helper, Utah	Price River
Upper Main Stem	Grand Junction, Colorado	Colorado & Gunnison Rivers
	Delta, Colorado	Gunnison & Uncompahgre Rivers
	Montrose, Colorado	Uncompahgre River
	Moab, Utah	Mill & Pack Creeks
	Dolores, Colorado	Dolores River
San Juan-Colorado	Farmington, New Mexico	Washes B&C
	Farmington, New Mexico	Animas River
	Shiprock, New Mexico	San Juan River
	Aztec, New Mexico	Aztec Arroyos
	Durango, Colorado	Junction Creek & Animas River

Lands subject to flooding are for the most part irrigated pasture, natural hay meadows, and range. In many areas, spring floodwater provides early irrigation and thus is a benefit to the economy. However, on a region-wide basis, floods generally cause damage to agricultural areas.

Streambank erosion is widespread on most, if not all streams. Land lost through erosion produces silt that deposits in downstream channels and reservoirs, and thus reduces their capacity and economic life. Based on very preliminary data, it appears that in 1965 there were about 180 miles of serious streambank erosion along the main streams and tributaries in the region. The annual loss of land is in the order of 300 to 400 acres and the monetary loss about $100,000. Additional erosion problems in the watershed areas are discussed in Appendix VIII - Watershed Management.

Estimates of future average annual flood damages were based on the RI-OBERS projections using 1965 prices and conditions of development as a base. Estimates of average annual flood damages in 1965 were made

by the standard-damage-flow frequency analysis for nine classifications of property and land use defined below. Average annual flood damages were estimated to be $2,792,000 in 1965. Projections of 1965 damages to target year 1980, 2000, and 2020 are discussed under "Future Needs."

Forest and range resources. - Losses or reduced yields from timberlands, brushlands, rangeland, creek bottom meadows, and wildlife and fishery habitat in forested areas.

Forest and range facilities. - Damages to campgrounds, recreation facilities (family units, water systems, picnic facilities), fences and corrals, wildlife facilities, roads, trails, and bridges.

Crop and pasture. - Damages to farmland such as crop loss or reduced yield or quality, increased production costs resulting from flooding and spreading of diseases and weed infestation, the inability to grow crops best adapted to the area, and crop losses due to suspension of irrigation water delivery or other loss of water.

Other agricultural. - Losses of stored crops and livestock, damage to machinery and fences, farm buildings and facilities, farm bridges and roads, and damage to farm levees, irrigation and drainage systems.

Land. - Damages caused by erosion and sediment deposition. These damages may be occurring on forest land, rangeland, intensively cultivated farmland, urban land, etc. It includes land lost during flooding to gullies, streambank cutting, channel changes, flood plain scour, and landslides caused by flooding. It also includes land rendered unproductive or less productive due to sediment deposition.

Residential damage. - Damage to single and multiple residences, houses, and apartments, including structures, contents, and property improvements.

Commercial damage. - Damage to businesses, hotels and motels, stores, and service establishments, including structures, furnishings, inventories, and property improvements and loss of business and wages resulting from this damage.

Industrial and utility damage. - Damage to manufacturing, processing, and fabricating plants and facilities, communication and utility lines and facilities, railroad lines, equipment and facilities; and losses resulting from the impact of these damages on the local and regional economy.

Public facilities damage. - Damage to highways and bridges, levee systems, irrigation diversions and canals, improved stream channels, municipal facilities, and public schools, all of which property is owned or administered by public agencies or non-profit political and semi-political organizations. Included in this classification are expenditures by Federal, state, and local agencies for flood fighting, repairing flood control works, and caring for evacuated people; costs for adjudicating suits for flood damages; and losses to the traveling public resulting from damaged highways and bridges.

PART V

FUTURE NEEDS

Projection Methodology

To adequately appraise the future needs for flood damage reduction, an evaluation of the expected future trends in average annual flood damages was undertaken. These projections of flood damages were used to identify potential problem areas where future structural and non-structural damage reduction measures will be needed.

The average annual flood damages, calculated for the base year 1965 by the standard damage-frequency relationship, were projected to the target years of 1980, 2000, and 2020. Future changes from the base year (1965) average annual damages bear a direct relationship to the changing value of flood damageable items within various flood plains. The basic parameters that were used in evaluating the anticipated changing value of the different flood plains were:

a. The projected agricultural acreage utilized within each flood plain and the expected changes in yields per acre were used to appraise the future changes in agricultural values. Future acreage of cropland and pasture in the flood plains for the various target years were projected by an examination of historical trends and an evaluation of foreseeable future developments. Since much of the Upper Colorado Region has semiarid or arid characteristics, future acreage projections were closely correlated with potential sources of irrigation water. Improvements in agricultural production technology (crop yields) will significantly increase the per acre value of the agricultural acreage within the flood plain areas. Future indices of crop yields were developed in the Economic Base and Projections Appendix. The increased use of commercial fertilizer, improved crop varieties, and more efficient farm irrigation and drainage practices were the major factors considered in projecting the growth in the crop yield indices. The future agricultural values were computed by applying the projected crop yield indices (in relation to the estimated future crop patterns) to the projected acreage in the various flood plains for the target years.

b. Future trends in the value of damageable forest and range resources and facilities were based on information from Appendix VI - Land Resources and Use and Appendix VIII - Watershed Management. Information included the projected future patterns of forest and range lands and the projected future developments in watershed areas.

Specific items which were considered in projecting the future damageable values include the expected yields from timber and range lands and the future program for the development of campgrounds, recreation and wildlife facilities, roads, trails, and bridges.

c. In projecting the future trends in the value of damageable residential and commercial property in the flood plain areas, projected changes in real per capita personal income and population density were used as the relevant indicators. Projected changes in real per capita income serve as a good overall measure of the changing value of residential and commercial property in the flood plain areas on a per capita basis. Future flood damages to residential and commercial property were correlated with projected changes in the patterns of population density. Some downward adjustment was made to the future density factors in expanding areas to offset an expected percentage increase in multiple storied structures which tend to reduce the quantity of flood damageable items susceptible to damage. The same indices of change were assumed to apply for both the residential and commercial values because of their mutual interties and a paucity of data to indicate any significant difference in their change on a small regional basis. Data, related to the future regional trends in real per capita personal income and future regional population characteristics presented in the Economics Base and Projections Appendix, were utilized in making the above projections.

d. Future industrial and utility values were projected on the assumption that the projected trends in industrial and utility employment and productivity presented in the Economics Base and Projections Appendix, will closely approximate the future investments in damageable plant and equipment by the industrial and utility sectors in the region's various flood plains. The tenability of this assumption seems valid when considering the types of industries and utilities operating within the region and the plant locations they require.

e. The projected changes in public facility values in the various flood plains were assumed to be a function of the changes in population and the projected increases in real per capita personal income for the different target years. Because a more intense use of the existing public facilities can be expected to occur in the future as population increases, the percentage changes in public facility values were made to lag the expected future changes in values for the residential and commercial property in the various flood plain areas.

By using these basic parameters, development factors were derived for each of the flood plains in the region. These development factors were used as indices for the projected changes in the average annual

flood damages for the target years 1980, 2000, and 2020. The following tabulation presents the 1965 base year and projected average annual flood damages for one reach of the Gunnison River and is included to illustrate the projection procedure and the magnitude of some of the derived development factors. Lines 3, 5, and 7 of the tabulation show the estimated average annual damage for the target years 1980, 2000, and 2020 if no additional flood damage reduction measures are adopted. Lines 8, 10, and 12 show the estimated residual average annual damages in the target years with the probable future flood damage reduction measures implemented.

Subregion: Upper Main Stem
Stream: Gunnison River
Reach: Curecanti Unit to Colorado River

Conditions	Average Annual Damages in $1,000							
	Crop & Pasture	Other Agric.	Land	Resid.	Comm.	Ind. & Util.	Public Facility	Total
	1965 Project Conditions and Prices							
1. 1965 Economic Conditions	19	3	6	16	9	8	36	97
2. Development Factor, 1965-1980	1.51	1.51	1.51	2.13	2.13	1.75	1.62	
3. 1980 Economic Conditions	29	5	9	34	19	14	58	168
4. Development Factor, 1965-2000	2.00	2.00	2.00	3.93	3.93	3.13	3.06	
5. 2000 Economic Conditions	38	6	12	63	35	25	110	289
6. Development Factor, 1965-2020	2.54	2.54	2.54	8.18	8.18	6.75	5.92	
7. 2020 Economic Conditions	48	8	15	131	74	54	213	543
	1965 Prices							
8. 1980 Economic & Project Conditions 1/	9	2	3	13	7	5	21	60
9. 2000 Economic & 1980 Project Conditions	11	3	4	24	13	9	40	104
10. 2000 Economic & Project Conditions 2/	11	3	4	16	9	7	29	79
11. 2020 Economic & 2000 Project Conditions	14	4	5	33	20	15	56	147
12. 2020 Economic & Project Conditions 3/	14	4	5	19	11	8	31	92

Future Flood Control Measures:
1/ Blue Mesa Reservoir
2/ Flood Plain Management, Grand Junction, Colorado
3/ Flood Plain Management, Delta, Colorado

Development factors similar to the factors in the tabulation were estimated for each principal stream and watershed area in the region. These factors reflect the different types of economic development expected and the degree of susceptibility of the developments to flood damage. Past trends in development and availability of undeveloped and partially developed lands in the flood plains were taken into consideration in the derivation of the factors. A part of the anticipated future growth would result from replacement of existing buildings and furnishings, structures, and equipment as they become obsolete.

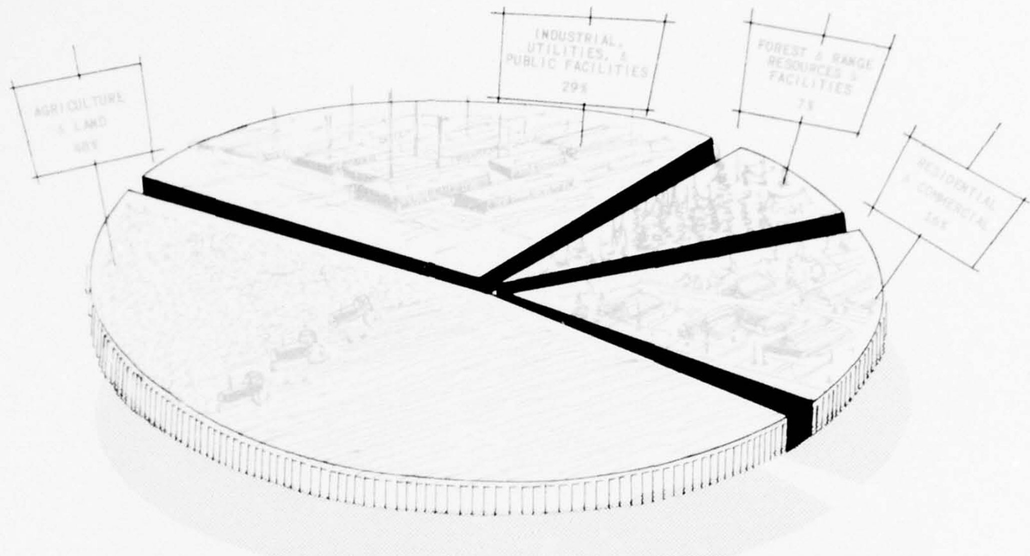
Future Needs

Flood damage reduction measures are needed to reduce the potential for loss of life, human suffering, and property damage caused by floodwater. The estimated magnitude of present (1965), and future flood damage that must be reduced to meet the needs of the region are summarized as follows:

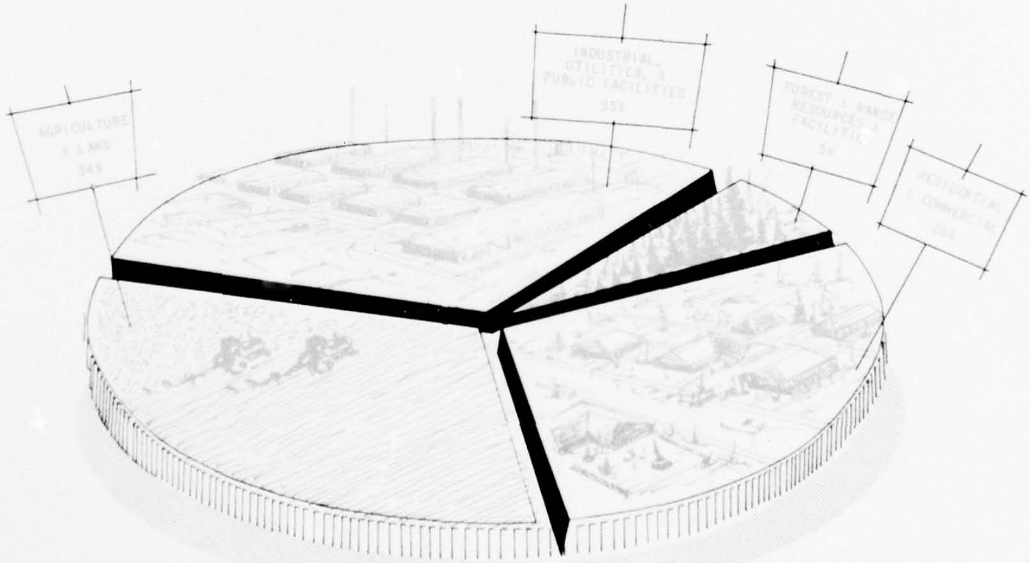
Subregion	Estimated average annual flood damages in $1,000 1/			
	1965	1980	2000	2020
Green River	998	1,469	2,306	3,558
Upper Main Stem	1,076	1,591	2,512	3,983
San Juan-Colorado	718	1,131	1,956	3,010
Region totals	2,792	4,191	6,774	10,551

1/ *Table 8 in the Watershed Management* Appendix includes a portion of the above damage data as well as other damage which occur in the watershed areas.

Estimates of future damage in the above tabulation are based on RI-OBERS projections and no further implementation of flood damage reduction programs after 1965. The increase in future damage would occur as a result of "normal" population growth and increased economic activity, and would not be "induced" as a result of future flood control developments. In addition to the nearly fourfold increase in flood damages projected by 2020, the percent of total flood damages classified as residential and commercial, industrial, and utility and public facilities will increase significantly as shown in the figure following this page.



1965



2020

UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

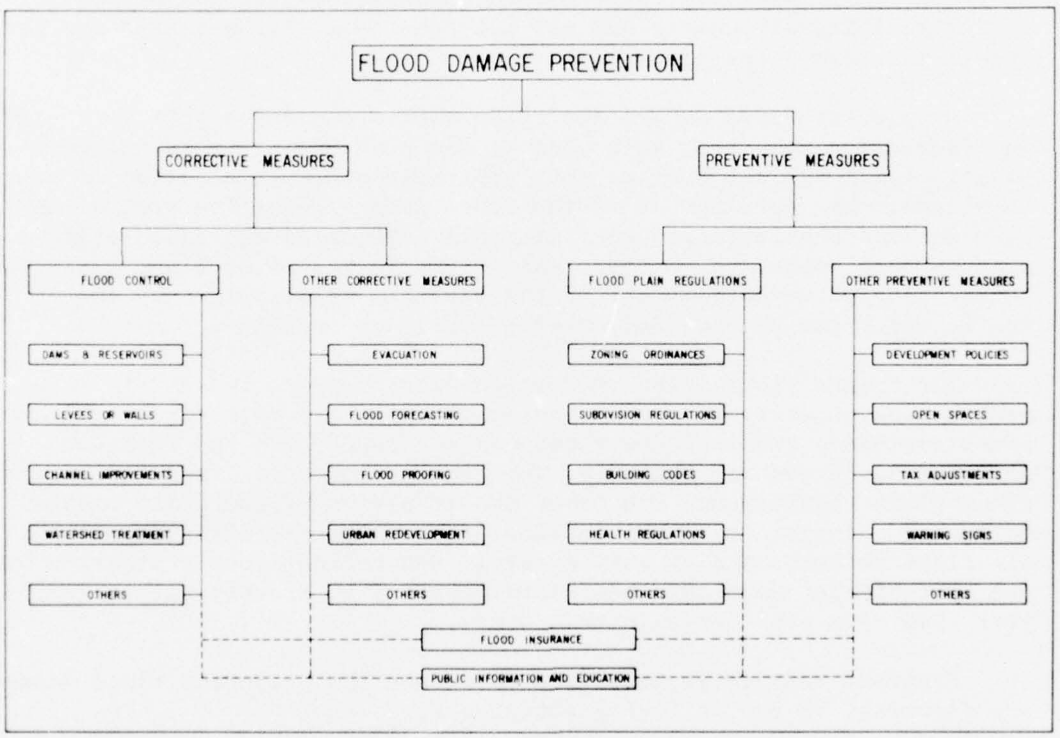
DISTRIBUTION OF AVERAGE ANNUAL FLOOD DAMAGE

APPENDIX IX

PART VI

MEASURES REQUIRED TO SATISFY FUTURE NEEDS

Flood damage reduction programs can be categorized under two general headings--corrective and preventive measures. Corrective measures reduce damages through control of water and preventive measures reduce damages through control of use of the flood plains. Principal features of these measures are indicated in the following diagram.



Each of the two general concepts of flood damage prevention offers advantages and disadvantages.

The initial cost of corrective measures is often higher than for preventive measures due to the cost of structures such as dams and reservoirs or levee and channel works; cost of flood proofing existing

structures; removal of damageable properties from flood plains; or other similar measures. Corrective measures sometimes involve the use of land resources which are needed or desired for other purposes and may encourage development of flood plain areas which should be reserved or restricted in development.

The cost of preventive measures may be higher in areas where existing developments would need to be removed to prevent flood damages. Preventive measures may not provide adequate protection and may be costly in restricting the use of lands needed to accommodate an expanding population or to provide needed facilities and services. Lands best suited for agricultural development, transportation facilities and, in some cases, industrial and urban development may be located within flood plains. Restrictions in the use of flood plain lands may cause needed community facilities or developments to be prohibitively costly and may not result in the best land use for the greatest number of people.

A plan for flood damage reduction should encompass both corrective and preventive measures, each used to the best advantage to preserve or utilize lands for the best or most desirable use. In addition to economic considerations, development of the flood damage reduction program must also include consideration of intangible advantages and disadvantages such as open space, recreation, and aesthetic values of flood plains and potential improvements in use of the environment resources by the public which can be provided by structural improvements.

The future flood damage reduction program presented herein is a combination of corrective and preventive measures, both structural and non-structural, and includes flood control reservoirs and retarding structures, levees and channels, watershed treatment, flood forecasting, flood plain regulations, and other non-structural flood plain management measures. Singly, or in combination, these measures will not eliminate all flood damages, and in many areas in the region flood protection will not be feasible under the conditions expected to prevail within the 55-year time span considered in this study.

Programs considered necessary to reduce the projected flood damages are discussed in the following paragraphs.

Improved Flood Forecasting

The present system of flood forecasting and warning in some areas of the region is inadequate to provide sufficient time for evacuation of people and contents of buildings from flood plains and for implementation of emergency measures for protection of property. Additional data collection units are also needed. Future improvements in the system would provide for:

a. Expansion of the data collection and reporting network, principally in the area of telemetry from remote area locations.

b. Satellite instrumentation and communication capability to provide:

(1) Surface temperature field.

(2) Temperature-moisture profile of the atmosphere.

(3) Snow area and depth determination.

c. Increased and improved radar coverage for determining precipitation rates and amounts.

d. Establishing more community flash flood warning programs.

e. Upgrading computer facilities for more rapid processing of data and increased research capabilities.

f. Increased research to improve hydrologic models.

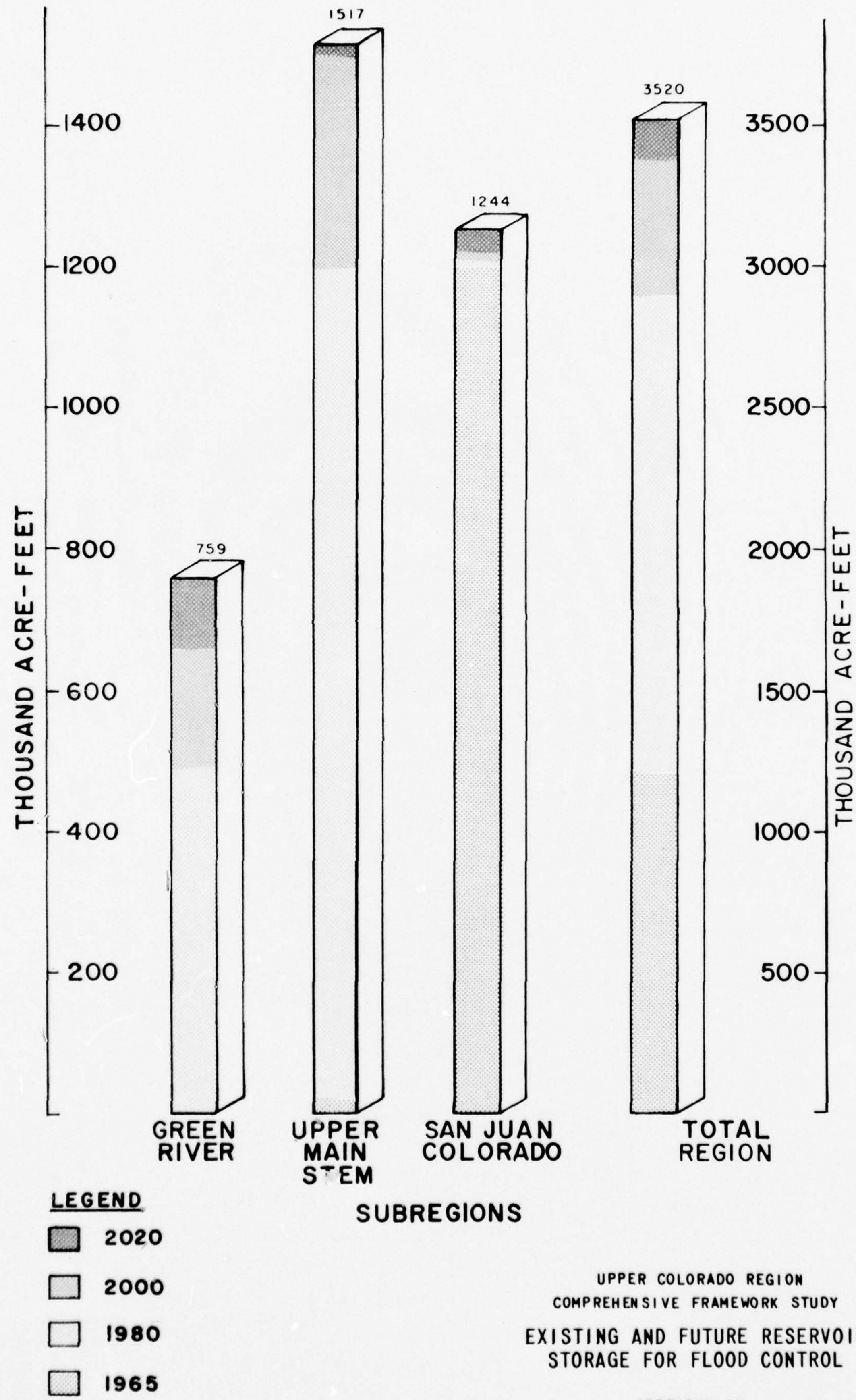
An early objective of flood forecasting is to implement complete coordination between Federal, state, and local government agencies in the collection of basic flood data and dissemination of forecasts. In those areas where flood control projects, watershed management practices, and/or a formal flood forecasting service are not feasible, a degree of protection for life and property can be provided through quantitative precipitation forecast and heavy rain warnings utilizing radar.

Costs of the improved flood forecasting program are based on records of costs for installations similar to the installations needed for the proposed flood control program. These costs are all Federal costs and are summarized incrementally by time frames in the following tabulation.

Subregion	Installation costs in $1,000			OM&R costs in $1,000		
	1966-1980	1981-2000	2001-2020	1966-1980	1981-2000	2001-2020
Green River	190	30	10	45	22	4
Upper Main Stem	100	120	0	39	30	0
San Juan-Colorado	0	90	0	0	23	0
Region totals	290	240	10	84	75	4

Flood Control Reservoirs

Reservoirs are considered to be an effective measure for the control of floods in many of the problem areas where existing and projected agricultural and urban areas need protection. The function of a reservoir is to store excessive floodflows and thus reduce flood heights in downstream areas. Reservoirs for flood control alone do not appear to be practical in the region, except for the small detention type reservoirs in the watershed areas. In this connection, the possible solution of flood problems in the region by reservoir storage has been under consideration for the past 30 years, and no single-purpose flood control reservoir has been found feasible. Accordingly, reservoirs for flood control on the main streams presented in this appendix are limited to joint use space available on a flood forecast basis in possible future multiple-purpose reservoirs. Flood control space would be evacuated in these reservoirs during the snowmelt runoff season only to the extent that the vacated space would be filled by the remaining runoff as determined by current snow surveys. Storage space necessary for the control of rain floods, except perhaps in very infrequent instances, would be available as a result of use of stored water for irrigation and other conservation uses. Table B, subregional Tables 6, and the figure following this page indicate the possible future multiple-purpose reservoirs to be operated for flood control. Reservoirs identified by name in Table B are shown on Plate 1, and those identified by number would be located within the watershed treatment areas shown on Plate 1. Five future multiple-purpose reservoirs, as footnoted in Table B, are completed or scheduled to be completed by 1972.



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

EXISTING AND FUTURE RESERVOIR STORAGE FOR FLOOD CONTROL

APPENDIX IX

TABLE B
FUTURE RESERVOIRS FOR FLOOD CONTROL 1/

SUBREGION AND RESERVOIR NAME (or number)	STREAM	STATE	FLOOD CONTROL CAPACITY (1000 ac-ft)	DRAINAGE AREA (sq. miles)
Green River				
	1966-1980			
Whiterocks	Whiterocks River	Utah	26	115
Uinta	Unita River	Utah	35	160
Starvation 2/	Strawberry River	Utah	152	1,045
Pot Hook	Slater Creek	Colorado	55	160
Fontenelle 2/	Green River	Wyoming	150	4,175
Savery	Savery Creek	Wyoming	18	190
Meeks Cabin 2/	Blacks Fork River	Wyoming	30	150
(Eleven)	Miscellaneous	Utah	21	125
		Subtotal	487	6,120
	1981-2000			
Tyzack	Brush Creek	Utah	18	85
Taskeech	Lake Fork River	Utah	66	135
Lost Park	Lost Creek	Colorado	22	15
Ripple	White River	Colorado	17	65
(Thirteen)	Miscellaneous	Utah	12	270
(Three)	Miscellaneous	Colorado	11	350
(Seven)	Miscellaneous	Wyoming	23	685
		Subtotal	169	1,605
	2001-2020			
Sweetbriar	South Fork White River	Colorado	25	150
Elk Park	Elk River	Colorado	50	380
(Six)	Miscellaneous	Utah	11	350
(Five)	Miscellaneous	Wyoming	17	390
		Subtotal	103	1,270
	Subregion Total		759	8,995
Upper Main Stem				
	1966-1980			
McPhee	Dolores River	Colorado	212	830
Ridgway	Uncompahgre River	Colorado	111	190
Ruedi 2/	Fryingpan River	Colorado	101	240
Blue Mesa 2/	Gunnison River	Colorado	748	3,500
(Two)	Miscellaneous	Utah	7	130
		Subtotal	1,179	4,890
	1981-2000			
Una	Colorado River	Colorado	140	7,500
Placita	Crystal River	Colorado	88	110
Saltado	San Miguel River	Colorado	65	300
(Nineteen)	Miscellaneous	Colorado	20	125
		Subtotal	313	8,035
	2001-2020			
(Eight)	Miscellaneous	Colorado	6	55
	Subregion Total		1,498	12,980
San Juan-Colorado				
	1966-1980			
(One)	Road Creek	Utah	1	20
(Eleven)	Miscellaneous	New Mexico	2	10
		Subtotal	3	30
	1981-2000			
(Six)	Miscellaneous	Utah	14	80
	2001-2020			
Caineville	Fremont River	Utah	20	1,250
(Two)	Miscellaneous	Utah	1	20
(Five)	Miscellaneous	Colorado	5	25
		Subtotal	26	1,295
	Subregion Total		43	1,405
	Region Total		2,300	23,380

1/ Named reservoirs are multiple-purpose with flood control included as a purpose. Other reservoirs indicated are detention type reservoirs primarily for flood control.

2/ Reservoirs will be operational by 1972. Fontenelle Reservoir was completed in 1964, but was not placed in operation for flood control until 1969. Blue Mesa Reservoir was completed in 1967.

Consideration was given to flood control storage on major streams in addition to those listed in Table B. About 100,000 acre-feet of flood control storage could be used in the Animas River Basin located within the San Juan-Colorado Subregion. Possibly the most effective location for storage on the stream is at the Teft site located upstream from Durango, Colorado. Quite extensive studies made in the past in connection with potential water conservation developments indicate that the cost of storage at the site is in the order of $500 per acre-foot for reservoirs in the 50,000 acre-foot capacity range and about $400 per acre-foot for capacities in the 85,000 acre-foot range. Such costs greatly exceed the combination of flood damage reduction and additional benefits from other foreseeable purposes; therefore, no development at the site is proposed. Flood control storage of 100,000 acre-feet or more could be used on several other streams in addition to the storage or other measures proposed, including the Dolores, Gunnison, White, Yampa, and Price Rivers; however, as in the case of storage on the Animas River, the reduction in flood damages and other beneficial uses would be small in comparison to the costs of such projects.

The estimated installation, operation, maintenance, and replacement costs by time frames for the future reservoir program are shown in Table C and Tables 10, 10a, and 10b. Estimates of costs and division of costs between Federal and non-Federal interests were available from prior allocations of costs for eight of the main stem reservoirs in the program. These costs were used as a guide in the apportionment of costs to the flood control function for other main stem reservoirs. The costs of the detention type reservoirs in the watersheds were estimated on an acre-foot basis, using unit costs for similar reservoirs that have been constructed and those in advance study stage in the region.

TABLE C
ESTIMATED COSTS OF FUTURE RESERVOIR PROGRAM
APPORTIONED TO FLOOD CONTROL

Subregion	State	Installation cost in $1,000		Annual OM&R costs in $1,000		Time frame
		Federal	Non-Federal	Federal	Non-Federal	
Green River	Utah	3,730	470	2	66	1966-1980
	Colorado	400	0	5	0	"
	Wyoming	800	0	10	0	"
	Utah	1,400	200	3	8	1981-2000
	Colorado	1,700	320	2	7	"
	Wyoming	3,040	760	0	16	"
	Utah	1,100	200	0	8	2001-2020
	Colorado	2,300	0	14	0	"
	Wyoming	2,120	370	0	9	"
Subregion totals		16,590	2,320	36	114	
Upper Main Stem	Utah	1,280	420	0	6	1966-1980
	Colorado	2,650	0	5	0	"
	Utah	0	0	0	0	1981-2000
	Colorado	4,840	760	7	14	"
	Utah	0	0	0	0	2001-2020
	Colorado	1,280	220	0	8	"
Subregion totals		10,050	1,400	12	28	
San Juan-Colorado	Utah	230	70	0	2	1966-1980
	Colorado	0	0	0	0	"
	New Mexico	890	300	0	4	"
	Arizona	0	0	0	0	"
	Utah	2,240	560	0	11	1981-2000
	Colorado	0	0	0	0	"
	New Mexico	0	0	0	0	"
	Arizona	0	0	0	0	"
	Utah	1,170	30	10	1	2001-2020
	Colorado	1,190	210	0	9	"
	New Mexico	0	0	0	0	"
	Arizona	0	0	0	0	"
Subregion totals		5,720	1,170	10	27	
Region totals		32,360	4,890	58	169	

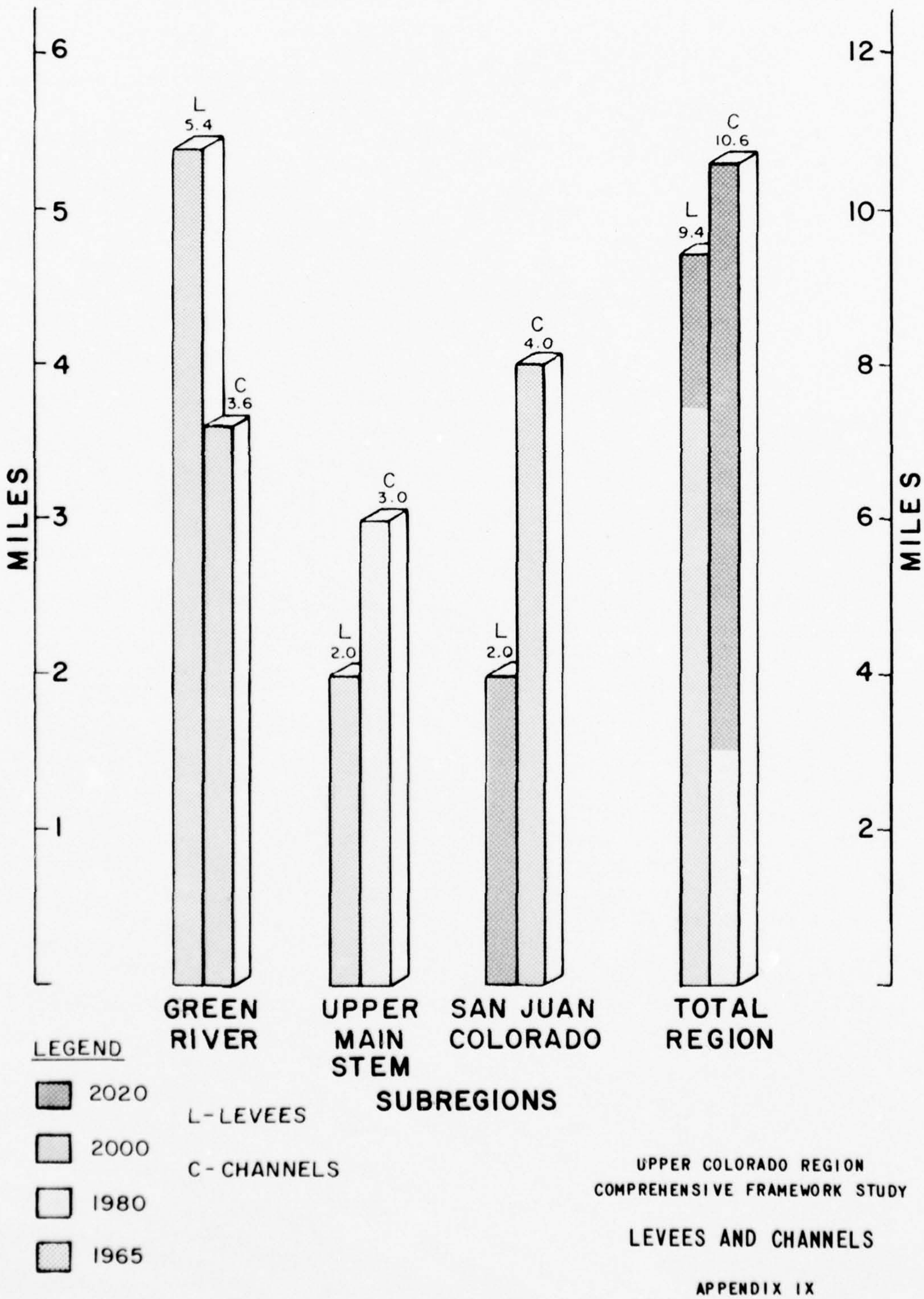
Levees and Channels

Levees protect local areas from flood losses by restricting the area of overflow. Usually they are located near the banks of channels, but may be located further away depending upon the local situation and the specific purpose they will serve. Channel improvements generally consist of widening, deepening, straightening, and clearing to remove major obstructions. Channel improvements and levees may be used together or separately to solve a given flood problem, or they may be used as a part of a systems solution to a problem which may include other structural or non-structural measures.

The future program of levee and channel improvements in the region is listed in the following tabulation, subregional Tables 7, and the figure following this page. The locations of the improvements are shown on Plate 1.

Subregion	Stream	State	Length in miles: Levees	Length in miles: Channels	Time frame
Green River	Duchesne River	Utah	1.0	0	1981-2000
	Fortification Creek	Colorado	2.4	1.6	"
	Bitter Creek	Wyoming	2.0	2.0	"
Subregion totals			5.4	3.6	
Upper Main Stem	Mill & Pack Creeks	Utah	0	3.0	1966-1980
	Dolores River	Colorado	2.0	0	1981-2000
Subregion totals			2.0	3.0	
San Juan-Colorado	Junction Creek	Colorado	0	1.6	1981-2000
	Animas River	Colorado	0	0.2	"
	Wash "B" & "C"	New Mexico	0	2.2	"
	Animas River	New Mexico	2.0	0	2001-2020
Subregion totals			2.0	4.0	
Region totals			9.4	10.6	

Estimates of costs of these improvements were based on updating costs from prior studies and reports, taking into consideration changed conditions. The Federal and non-Federal costs of the future levee and



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

LEVEES AND CHANNELS

APPENDIX IX

channel program are shown by subregions, states, and time frames in the following tabulation and Tables 10, 10a, and 10b. The assignment of program costs to Federal and non-Federal interests is based on the Federal Government paying for levee and channel work, and the local interests paying for necessary lands, easements, and rights-of-way, relocations and modifications to utilities including bridges and roads, and all annual operation, maintenance, and replacement costs.

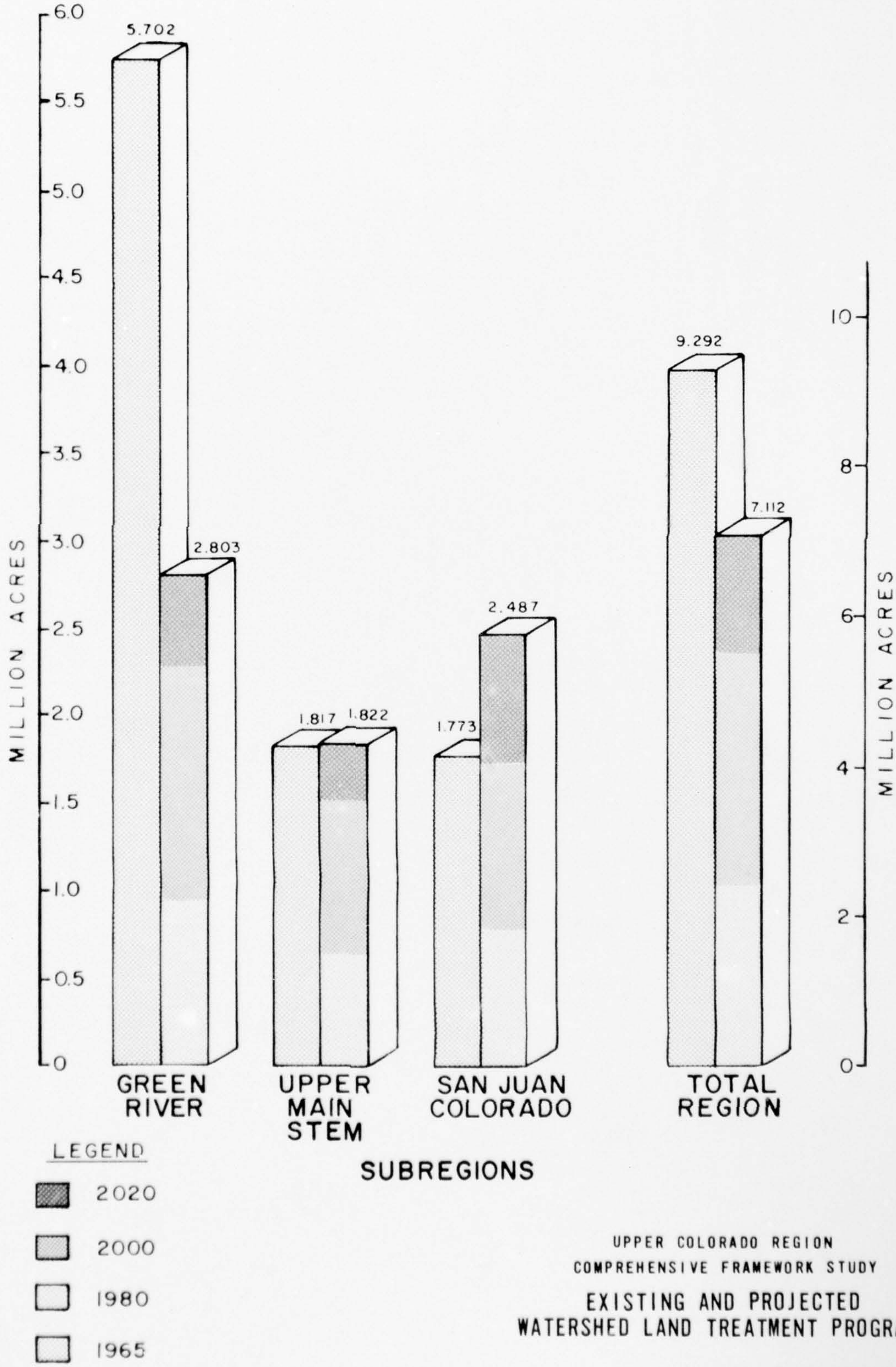
Subregion	State	Installation cost in $1,000: Federal	Installation cost in $1,000: Non-Federal	Annual OM&R costs ($1,000): Federal	Annual OM&R costs ($1,000): Non-Federal	Time frame
Green River	Utah	300	100	0	3	1981-2000
	Colorado	300	100	0	3	"
	Wyoming	1,000	400	0	7	"
Subregion total		1,600	600	0	13	
Upper Main Stem	Utah	3,000	250	0	5	1966-1980
	Colorado	400	100	0	4	1981-2000
Subregion totals		3,400	350	0	9	
San Juan-Colorado	Colorado	3,050	250	0	6	1981-2000
	New Mexico	2,000	250	0	4	"
	New Mexico	1,100	400	0	6	2001-2020
Subregion totals		6,150	900	0	16	
Region totals		11,150	1,850	0	38	

Watershed Management and Land Treatment

The flood control objective of watershed management and land treatment is to reduce flood peaks, prevent excessive erosion with its damaging sedimentation-debris effect, and improve the hydrologic function of watersheds. These objectives are accomplished by structural and non-structural measures to restore and preserve soil stability and productivity, and the proper soil-water plant relationship. Structural measures for flood control and their estimated costs are included in the Flood Control Reservoir Program in Tables B and C, and in the Levee and Channel Program tabulations on pages 34 and this page. Non-structural measures consist of contour trenching, terracing, furrowing, pitting, gully plugs, revegetation, tree

and shrub planting, and other soil stabilization practices. These measures, in conjunction with careful land use management, reduce flood peaks and sediment production. A vital role of watershed management and land treatment is to protect areas above main stream structures.

The proposed watershed land treatment on 7.1 million acres and the installation of 74,000 small water control facilities related to flood control are shown in the tabulation on page 37. The figure following this page shows existing and future acreage requiring future land treatment measures. This program is from Appendix VIII, "Watershed Management," and is a part of a comprehensive watershed plan for the region. Costs specifically for flood control cannot be separated from the comprehensive watershed program costs in appendix VIII and are not included herein.



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

EXISTING AND PROJECTED
WATERSHED LAND TREATMENT PROGRAMS

APPENDIX IX

Subregion and state	Land treatment (1,000 acres) 1/			Water control facilities (number) 2/		
	1966-1980	1981-2000	2001-2020	1966-1980	1981-2000	2001-2020
Green River						
Utah	339	319	211	3,025	3,442	4,554
Colorado	157	255	115	560	877	252
Wyoming	478	728	201	191	324	115
Subregion total	974	1,302	527	3,776	4,643	4,921
Upper Main Stem						
Utah	29	41	32	105	335	627
Colorado	612	832	276	12,939	19,516	4,956
Subregion total	641	873	308	13,044	19,851	5,583
San Juan-Colorado						
Utah	212	277	194	898	2,347	4,097
Colorado	235	169	62	2,736	1,694	481
New Mexico	327	446	384	3,006	2,711	1,896
Arizona	23	32	126	860	756	560
Subregion total	797	924	766	7,500	7,508	7,034
Region total	2,412	3,099	1,601	24,320	32,002	17,538

1/ Includes vegetation management, contour furrowing and trenching, ripping, pitting, terracing, revegetation, and stabilization of roads, trails, dunes, and mined areas.

2/ Includes small detention dams, check and drop structures, diversion dams, and dikes and debris basins.

Non-structural Flood Plain Management

Although flood plain management can be considered as embodying all the actions which can be taken to achieve desired objectives in flood plain land use, the following discussion is limited to non-structural preventative measures. Some of the non-structural flood plain management

techniques are described in the following paragraphs and in the figure following this page illustrates the application of these techniques A discussion of the specific non-structural measures of the program follows the general discussion below.

a. Zoning. - Zoning is a legal measure that state, county, and local agencies could implement and enforce to effectively reduce the flood damage potential of an area in accordance with a planned program of development and land use. Zoning may require designation of the channel and portions of the adjoining flood plain as a primary floodway for passage of floodwater. Other areas of the flood plain, or secondary floodway, could be developed, provided that adequate measures were taken to reduce the damage potential consistent with the risk involved. Zoning measures insure the safekeeping of property for the health, welfare, and safety of the general public. Floodways may be zoned for different types of development, such as residential, commercial, agricultural, and recreational, or for retention as open spaces. Limiting elevations could be established, below which certain types of development would not be permitted.

b. Subdivision regulations. - Subdivision regulations could be adopted that would state requirements for street widths and minimum elevations, drainage structures, and minimum building elevations. This type of measure could also specify the manner in which land adjoining streams could be subdivided and could require subdividers to provide adequate waterways for passage of floodflows.

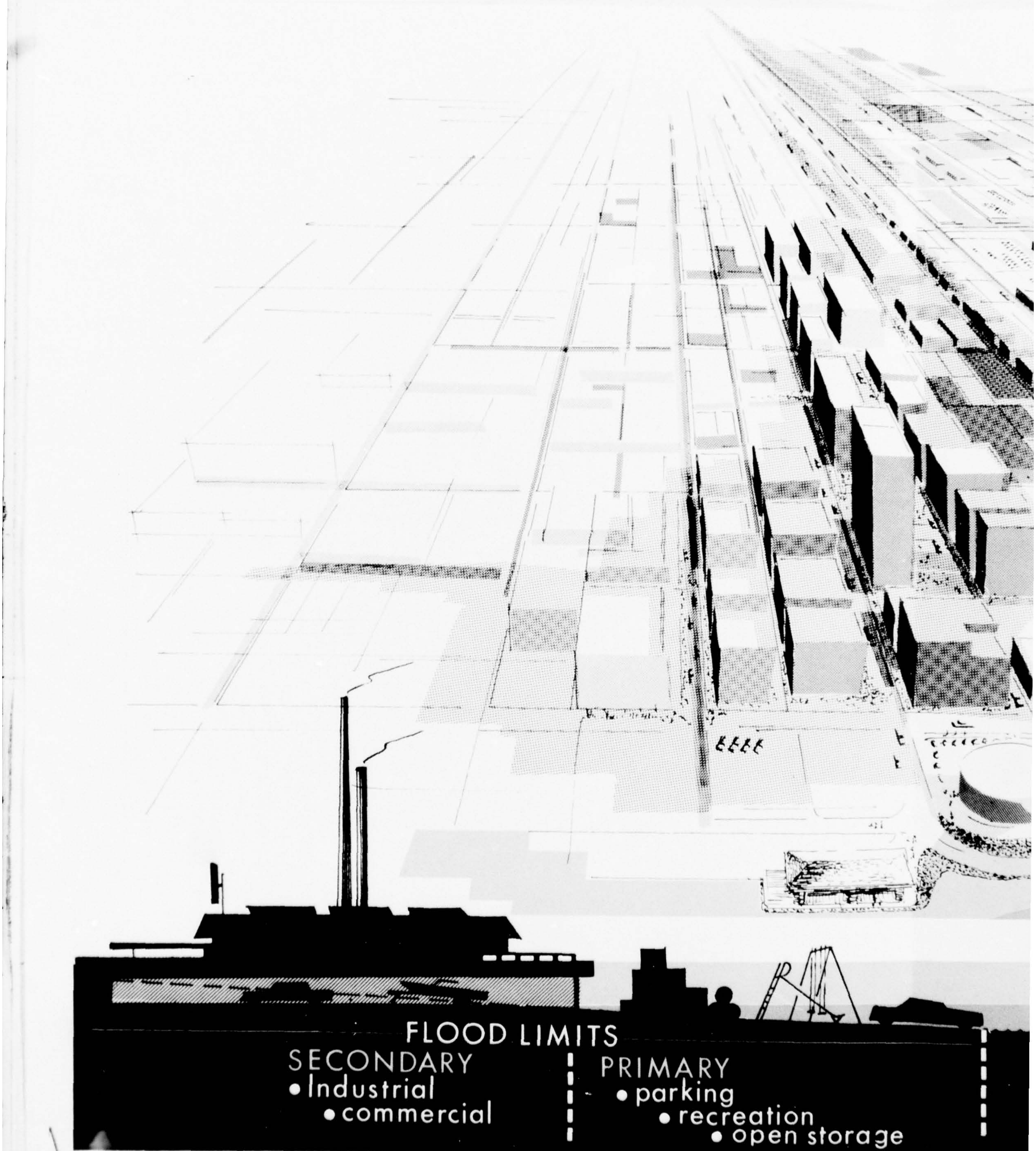
c. Building codes. - Local governmental agencies could adopt building codes that would assist in preventing future flood damages. These codes could prescribe types of materials that would not be damaged by water, and establish basement and first floor elevations.

d. Floodproofing. - Floodproofing, a combination of changes and adjustments to properties and structures, could be employed for the reduction or elimination of flood damages. Floodproofing includes but is not limited to:

(1) Providing permanent or temporary water-tight covers for building openings.

(2) Raising existing buildings.

(3) Providing individual dikes around existing or future structures.



FLOOD LIMITS
SECONDARY
• Industrial
• commercial
PRIMARY
• parking
• recreation
• open storage

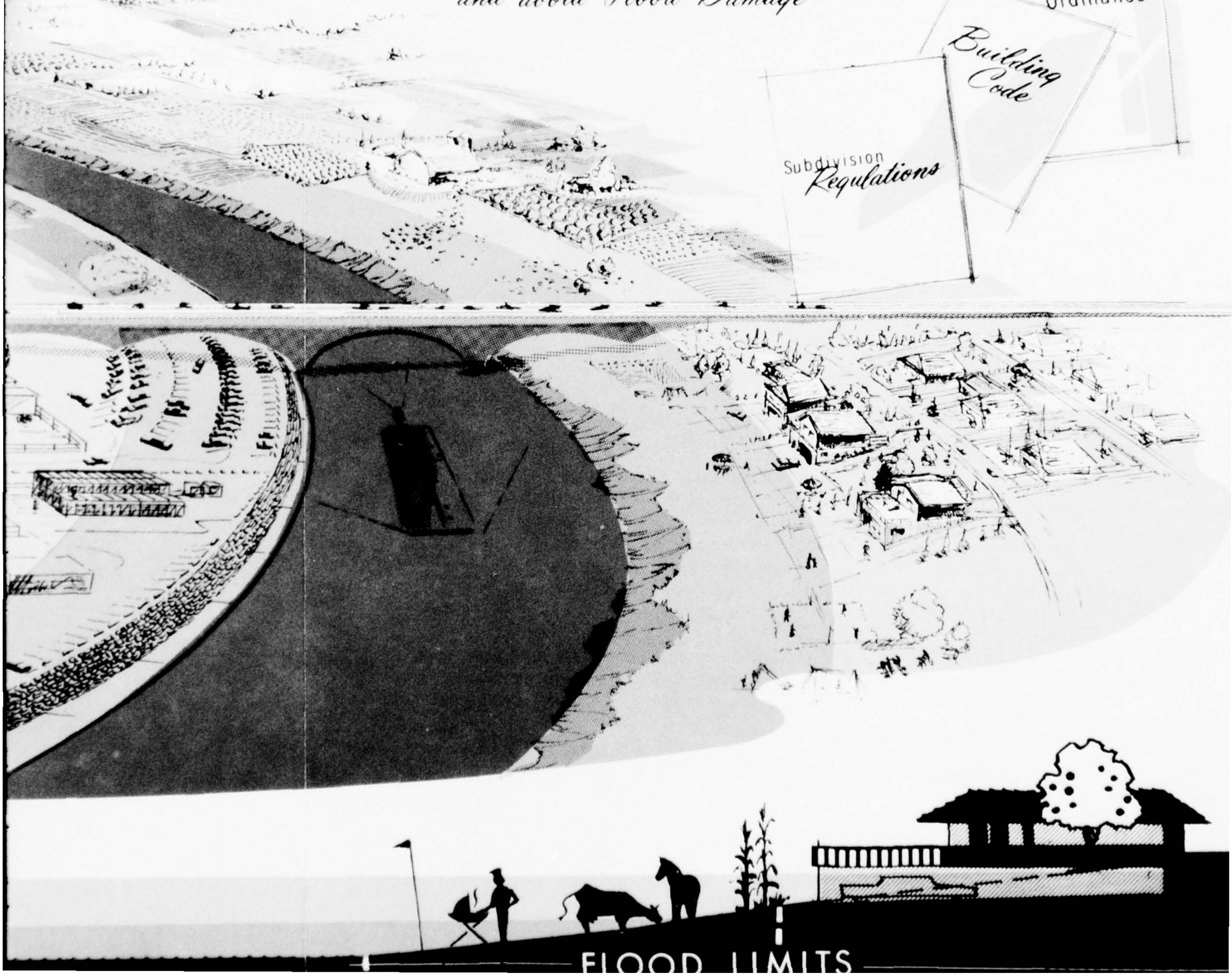
FLOOD I

. . . to

and a

FLOOD PLAIN *Regulations*

... to encourage wise use and avoid Flood Damage



(4) Protecting roads and utilities.

(5) Anchoring floatable structures and facilities.

e. Evacuation. - Permanent evacuation of flood plain areas could be used to reduce the flood damage potential. Such a measure would involve removal of all buildings and property in the flood plain. Temporary evacuation of persons, livestock, and personal property from flood prone areas could be accomplished when a flood threat exists, and is effective when combined with a reliable flood forecasting system.

f. Open space development. - Areas in the flood plain could be set aside for development as parks, recreation areas, playgrounds, or golf courses where such development would not interfere with, or be seriously damaged by floodwaters, or could be left as natural scenic areas. A number of locations in flood plain areas throughout the Upper Colorado Region can be developed for such purposes.

g. Other measures. - Other measures could be provided in the flood plain, such as warning signs, tax adjustments, building financing, flood insurance, and reconstruction of bridges and culverts, which could also reduce or eliminate future damage in the flood plain.

An important element in the application of non-structural flood plain management techniques is the Federal Flood Plain Management Program. This program was established to provide Federal, state, and local governmental agencies flood hazard information that would serve as a guide for future development of land, provide a basis for regulation of land use to avoid future flood damage, and assure that Federal agencies will take proper cognizance of the flood hazards associated with the development and management of flood plain areas. As it is presently constituted, the program includes the following services.

a. Flood plain information reports are prepared at the request of state and local governmental agencies to delineate flood problems in communities throughout the nation. These reports contain illustrative and narrative material on past floods, and similar data on floods that may reasonably be expected to occur within a community area in the future.

b. Technical services and guidance are provided to Federal, state, and local governmental agencies for the following: interpretation and application of data in flood plain information reports; preparation of flood plain regulations; suggestions for floodway areas and evaluations on the effect of floodways; information on flood damage reduction

by various structural and non-structural measures; and evaluation and use of flood hazard data to permit wise decisions on the locations of public buildings and other publicly owned facilities, and on subdivision development or other land uses where there is a Federal interest.

c. Research efforts are being conducted to improve methods and procedures of flood damage prevention and abatement. The research effort includes studies of and the means for illustrating alternative ways of reducing flood damages. Prepared guides and pamphlets are available for the use of Federal, state, and local governments and private citizens in planning and implementing programs to reduce the flood damage potential of an area.

d. Comprehensive planning efforts at all appropriate governmental levels are considering flood control works, flood proofing, flood forecasting, zoning, subdivision regulations, building codes and policies that will work in combinations or separately to provide the best solution to the flood problem associated with the community. Engineering services and technical assistance and guidance are provided throughout the course of planning and implementing measures needed to reduce the flood damage potential.

Because of the present sparse population and lack of extensive developments in the flood plains of the region, there is good opportunity and need for implementation of non-structural flood damage reduction measures. Because the existing and future multiple-purpose reservoirs can provide only a relatively low degree of flood protection to downstream areas, it is particularly important to provide for non-structural flood prevention practices to supplement structural measures.

Initial steps have been taken to implement non-structural flood plain management practices where feasible and applicable. Flood plain information studies have been requested for all urban areas with potential flood problems in Utah and for Grand Junction and vicinity in Colorado. It is expected that requests for studies of other communities will be made in the near future. These initial studies will be undertaken and completed within an initial time frame of the framework studies (1965-1980). Studies of additional areas and updating of the initial studies will be accomplished in the later time frames. In consonance with current practices, projections of flood plain information studies and implementation of non-structural preventive measures was limited to urban areas; however, extension of the study areas and implementation of non-structural flood control measures for agricultural areas may prove of value in the future.

Consideration of non-structural flood prevention techniques and the anticipated urban growth patterns indicated that the probable methods to be employed, other than dissemination of flood data by way of the flood plain information reports, would be by zoning and flood proofing in existing and projected urban areas.

Selected communities where non-structural flood prevention measures will be needed and the estimated time frame of the implementation of such measures is shown in the tabulation below. Current non-structural flood prevention actions involving preparation of flood plain information reports are not included in the tabulation.

Subregion	State	City	Time frame
Green River	Utah	Price	1981-2000
	Utah	Castlegate	"
	Utah	Helper	"
Upper Main Stem	Colorado	Montrose	1981-2000
	Colorado	Grand Junction & vicinity	"
	Colorado	Delta	2001-2020
	Utah	Moab	"
San Juan-Colorado	New Mexico	Farmington	1981-2000
	New Mexico	Shiprock & other communities along San Juan River	"
	Colorado	Durango	2001-2020

Estimates of costs of the flood plain management program are based on data gathered in the preparation of flood plain information studies and studies made in the past of urban flood problems. These costs are for the non-structural portions of the program and include the costs of flood proofing existing buildings and structures within primary flood plains (areas flooded by a selected flood, usually the estimated once in 100-year event), costs of landfills, and other methods of raising new structures outside the primary flood plain but within the flood plains

of floods larger than the 100-year event, costs of zoning, preparation of subdivision regulations, and other measures that may be used to regulate flood plains. Under existing authorities the installation and OM&R costs of non-structural portions of flood plain management programs, except the costs of programs on government-owned lands, are a local responsibility. It is possible that in the future costs may be shared by Federal and local interests depending on the merits of the individual case. The Federal portion of installation cost in the tabulation is the cost of preparing flood plain information reports for the program and for furnishing other technical services and guidance to state and local agencies. Costs of current studies, cited previously, are relatively minor and are not included in the tabulation. Better estimates of the costs of the flood plain management program can be prepared when more detailed data are available from future flood plain information studies. Estimated costs of the flood plain management program are as follows:

Subregion	State	Installation cost in $1,000		Annual OM&R costs in $1,000		Time frame
		Federal	Non-Federal	Federal	Non-Federal	
Green River	Utah	30	970	0	9	1981-2000
Upper Main Stem	Colorado	40	1,960	0	16	1981-2000
	Utah	20	980	0	9	2001-2020
	Colorado	30	1,170	0	10	"
Subregion totals		90	4,110	0	35	
San Juan-Colorado	New Mexico	70	2,530	0	21	1981-2000
	Colorado	30	1,170	0	10	2001-2020
Subregion totals		100	3,700	0	31	
Region totals		220	8,780	0	75	

Land Requirements

Estimates of land requirements needed for the future flood control program are given in the following tabulation. Included in the estimates are lands for levees and channels and watershed detention reservoirs. No lands would be required for flood control in the multiple-purpose

reservoir programs, improved flood forecasting, and non-structural components of flood plain management. Lands required for the non-structural portions of watershed projects (which are also used for other compatible programs) are included in the program in Appendix VIII, Watershed Management.

Subregion	State	Land requirements in acres 1966-1980	1981-2000	2001-2020
Green River	Colorado	290	790	150
	Utah	1,790	1,500	890
	Wyoming	320	1,350	760
Subregion total		2,400	3,640	1,800
Upper Main Stem	Colorado	150	1,050	420
	Utah	550	150	130
Subregion total		700	1,200	550
San Juan-Colorado	Colorado	80	100	260
	Utah	570	920	280
	New Mexico	130	110	70
Subregion total		780	1,130	610
Region totals		3,880	5,970	2,960

Environmental Considerations

A primary consideration in the development of flood damage reduction programs--either structural or non-structural, single, or multipurpose--is the environmental effects of the programs. Early in the detailed investigation stage of such programs, inventories are made of the natural environmental qualities of project areas and plans initiated to preserve and enhance these qualities. Environmental considerations include but are not limited to recreational, fish and wildlife, aesthetic aspects of project areas, and the protection or preservation of historic or archeological resources.

Recreation developments provide for water-oriented activities such as boating, swimming, water skiing, and fishing; and land based activities such as horseback riding, hiking, bicycling, picnicking, and rest areas. Programs to preserve, mitigate, and enhance fish and wildlife resources include the maintenance of minimum flows from reservoirs, retention of in-channel vegetation where possible, planting of vegetative strips along but outside channel and levee improvements, and maintenance of favorable watershed conditions. Aesthetic aspects of the project areas involve the planting of trees, shrubs and ground cover, the use of properly designed signs, structures, and access roads with native plantings alongside.

Environmental planning also include consideration of the preservation and enhancement of existing open space or the establishment of open space to be used in consonance with zoning and development plans of local and regional planning agencies. A consideration in a future flood control program is the preservation of streams or certain reaches thereof in accordance with the Wild and Scenic Rivers Act of 1968 whenever legal and local conditions are applicable.

Summary of Costs

The estimated cost of the flood damage reduction program, based on July 1965 prices, is summarized by subregions, states, and time frames on Table D. Tables 10, 10a, and 10b indicate costs of structural measures (channels, levees, and reservoirs) and non-structural measures (improved flood forecasting and non-structural flood plain management programs). The cost of watershed practices for flood control are not included. These costs are a part of the watershed costs given in the Watershed Management Appendix.

Accomplishments

The future flood damage reduction program proposed in this appendix would contribute to the well-being of the people by preventing possible loss of life, suffering, damage to property, and loss of goods and services. Estimates were made of the reduction in damages, in terms of 1965 dollars, the proposed program would produce for each time frame considered in the study. These estimates are shown on Table 8. The estimated total reduction in flood damages at the end of each time frame is indicated in the first tabulation on page 47. A general discussion of the effectiveness of the programs in the prevention of flood losses follows.

TABLE D
COST OF FLOOD CONTROL PROGRAM BY SUBREGIONS AND STATES
($1,000)

Subregion/State (Federal cost) (non-Federal cost)	1966-1980 Install-ation	1966-1980 Annual OM&R	1981-2000 Install-ation	1981-2000 Annual OM&R	2001-2020 Install-ation	2001-2020 Annual OM&R
Subregion						
Green River						
(Federal)	5,120	62	7,800	27	5,530	18
(non-Federal)	470	66	2,850	53	570	17
Subregion total	5,590	128	10,650	80	6,100	35
Upper Main Stem						
(Federal)	7,030	44	5,400	37	1,330	0
(non-Federal)	670	11	2,820	34	2,370	27
Subregion total	7,700	55	8,220	71	3,700	27
San Juan-Colorado						
(Federal)	1,120	0	7,450	23	3,490	10
(non-Federal)	370	6	3,590	42	1,810	26
Subregion total	1,490	6	11,040	65	5,300	36
Region total	14,780	189	29,910	216	15,100	98
State						
Arizona	0	0	0	0	0	0
Colorado						
(Federal)	3,150	49	10,440	39	4,840	14
(non-Federal)	0	0	3,490	49	2,760	37
State total	3,150	49	13,930	88	7,600	51
New Mexico						
(Federal)	890	0	2,160	23	1,100	0
(non-Federal)	300	4	2,780	25	400	6
State total	1,190	4	4,940	48	1,500	6
Utah						
(Federal)	8,430	47	4,010	25	2,290	14
(non-Federal)	1,210	79	1,830	31	1,210	18
State total	9,640	126	5,840	56	3,500	32
Wyoming						
(Federal)	800	10	4,040	0	2,120	0
(non-Federal)	0	0	1,160	23	380	9
State total	800	10	5,200	23	2,500	9
Region total	14,780	189	29,910	216	15,100	98

Flood forecast services for the period 1951-1965 show a national average annual savings of about 10 percent of the average annual flood damages in terms of 1965 dollars. That percentage is considered to be representative for damage in the urban areas in the Upper Colorado Region, but would be less effective for the farm and watershed areas.

The effectiveness of reservoirs to control floods and reduce damage depends on the location of the reservoir site with respect to flood damage areas, the amount of storage provided, and how the storage is operated. Major reservoirs in the program would be multiple-purpose operated on a flood forecast basis and would not provide a high degree of protection. Generally, these reservoirs would prevent bank overflow for floods in the 25- to 50-year frequency range. The small reservoirs in watershed areas would be operated primarily for flood control and would provide protection in the 100-year flood frequency range at the reservoir site. The protection at damage areas is often less than at the reservoir site due to uncontrolled inflow downstream from the reservoir. Where reservoirs would not provide the protection needed, particuularly in urban areas, supplemental channel work and non-structural flood plain management programs would be used.

The proposed channels and levees would provide overflow protection against floodflows having a frequency of occurrence of not less than once in 100 years on the average and would be for protection of urban areas. The flood magnitude and degree of protection would be selected on the basis of detailed studies made subsequent to authorization.

The watershed management and land treatment portions of the future program would substantially reduce flood damage to forest lands and facilities, isolated farmlands, farm-ranch buildings, campgrounds, forest-county road systems, and fish and wildlife habitats. Also, they would prevent the erosion of streams and watershed areas, deposition of silt and debris on creek bottom meadow-hay lands, and the lowering of water tables due to stream cutting and scouring. A further benefit would be to prevent loss of soil fertility essential to the maintenance of adequate growth of forage for livestock and wildlife.

Although structural measures are needed to control floodflows to protect existing and projected economic developments in the flood plains, non-structural flood plain management measures are an essential element of the program for flood damage reduction. Non-structural measures will prevent 20 to 40 percent of future flood damage in urban areas. Timely zoning of the flood plain before development, adoption of subdivision regulations that establish realistic standards to prevent damage from flooding, use of flood proofing on existing and future facilities in

floodways and sound community planning can be effective measures to reduce flood damages and to prevent adverse ecological effects. In many urban areas, non-structural measures will supplement protection provided by existing or proposed reservoirs and by necessary levee and channel works; in other areas, non-structural flood plain management will be the principal program for flood control.

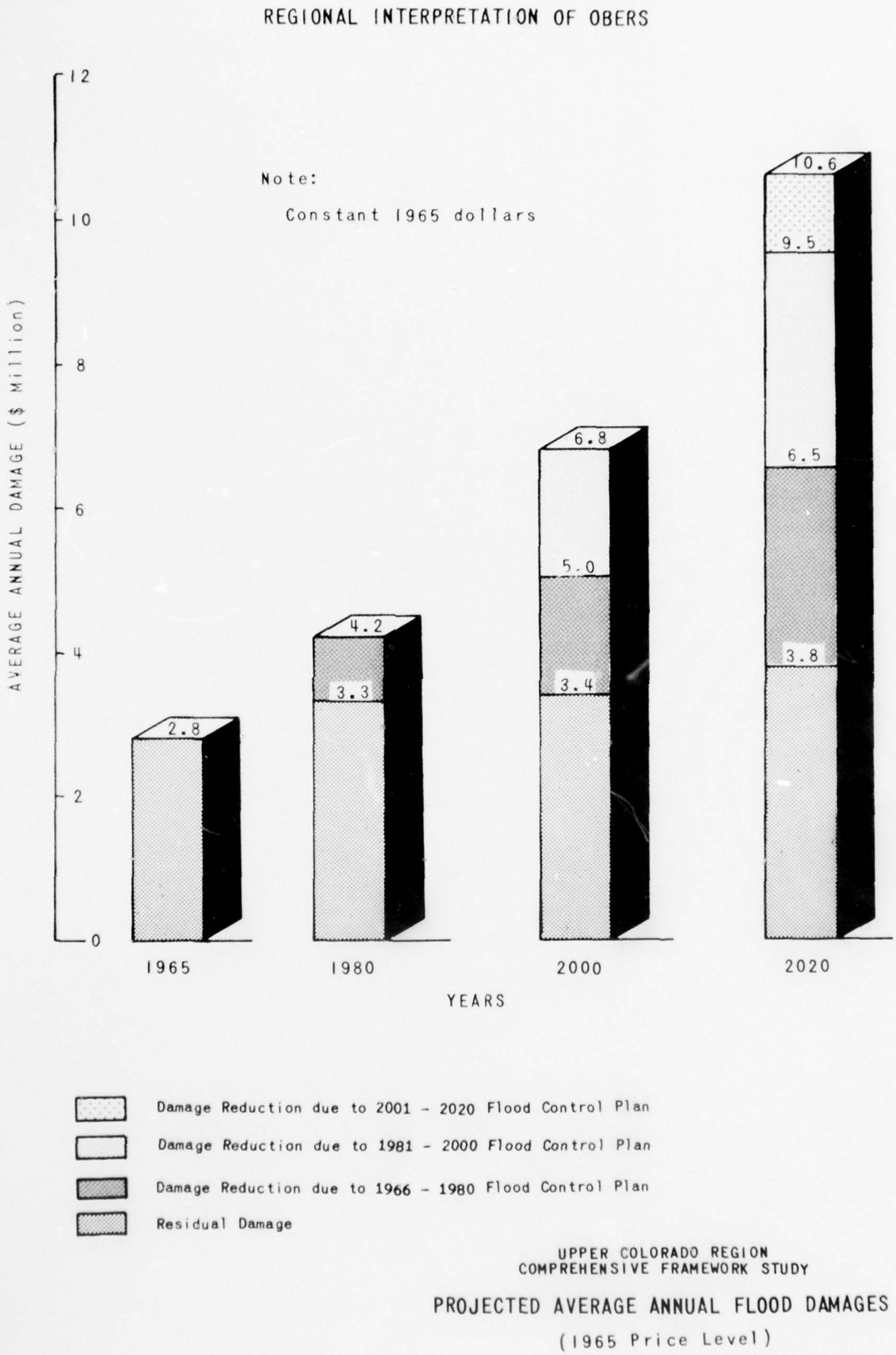
A measure of the accomplishments of the proposed flood control program is the difference in average annual flood damages with the 1965 program and with the future program. This difference is indicated by subregions in the following tabulation.

Subregion	Estimated average annual flood damage reduction in $1,000		
	1980	2000	2020
Green River	302	1,053	2,115
Upper Main Stem	485	1,431	2,725
San Juan-Colorado	153	871	1,904
Region totals	940	3,355	6,744

The residual damages with the future program in operation are shown in the following tabulation.

Subregion	Estimated average annual flood damages in $1,000 with future flood control program in operation			
	as of 1965	as of 1980	as of 2000	as of 2020
Green River	998	1,167	1,253	1,443
Upper Main Stem	1,076	1,106	1,081	1,258
San Juan-Colorado	718	978	1,085	1,106
Region totals	2,792	3,251	3,419	3,807

The effect on the estimated future damages by the projected flood control program is graphically shown in the figure following this page.



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

PROJECTED AVERAGE ANNUAL FLOOD DAMAGES

(1965 Price Level)

APPENDIX IX

PART VII

DISCUSSION, CONCLUSIONS, AND SUGGESTIONS

Discussion

The objectives of this appendix are to inventory the flood problems as of 1965, make an assessment of future flood problems based on RI-OBERS projections of population and economic activity in the region, and to outline a plan for reduction of flood damage. The appendix, together with 15 other appendixes covering other pertinent resources subjects, are used to formulate a basin-wide plan for the preservation and the timely development and management of the water and related land resources of the region.

The future flood damage reduction program consists of improved flood forecasting, 2,300,000 acre-feet of flood control storage in single- and multiple-purpose reservoirs, 9 miles of levees, 11 miles of channel improvements, 7,112,000 acres of watershed management, land treatment and water control facilities, flood plain zoning, and other flood plain management measures. Non-structural measures would be a primary means of flood damage reduction as well as a supplement to structural measures.

The estimated installation cost of the program, based on July 1965 conditions and prices, through 2020 is \$59.8 million, of which \$44.3 million would be a Federal cost and \$15.5 million a non-Federal cost. These costs do not include the estimated costs of watershed improvements related to flood control which are a part of the costs of an overall watershed program proposed in Appendix VIII, Watershed Management.

The reduction in average annual flood damage for the program is estimated at about \$6.7 million by year 2020.

The flood control program presented herein was developed specifically to meet the needs and requirements for reduction of flood damage. Coordination with plans developed to satisfy other water or land resource needs will be required to avoid adverse effects on other resource plans. The interrelationships and effects of the flood control program on the resource plans are discussed in the General Programs and Alternatives Appendix. The program would not involve any water supply depletion but, in connection with the watershed management appendix, may add to the total water supply of the region.

The program is based on RI-OBERS projections of population and economic activities in the region. Should future events not follow the projections, the program would have to be changed to meet future conditions. Detailed investigations made prior to authorization of future projects may indicate the need to modify the program. Accordingly, the program presented is to be considered as one possible alternative to the solution of future flood problems in the region. Other possible alternative levels of development are presented in Supplement A.

Ample authority exists at the Federal level to investigate flood problems in the Upper Colorado Region and to recommend implementation of programs found to be needed and feasible. The specific authorities of all Federal agencies are cited in Appendix III, Legal and Institutional Environments. Colorado is the only state in the region with legislative authority to provide the necessary local assurances for local flood protection works (levees and channels and multiple-purpose reservoirs where a portion of the flood control costs are allocated to the local interests). In states that do not have the authority to provide the necessary assurances, the responsibility falls to the county or counties in which the works are located or would be benefited. The local share of project costs often exceeds the financial ability of the local interests and may prevent or delay construction of needed projects.

Actions to implement zoning, building regulations, flood proofing, and non-structural flood plain management practices of the program are presently the responsibility of local governments. Under present policy, the installation and annual operation, maintenance, and replacement costs of non-structural flood plain management programs are assigned to the local interests. Due to limited financial ability of local interests, these programs may not be implemented or may be delayed. It is possible that, in the future, costs of non-structural flood plain management programs may be shared by Federal and local interests depending upon the merits of individual cases.

Authority exists for Federal land management agencies to implement watershed management and land treatment programs. The lack of funds remains the most severe constraint in the implementation of watershed projects.

The programs proposed herein cannot be implemented unless the needs develop as projected and ample funds for investigation and construction are made available as needed.

Conclusions

Flood problems exist in the Upper Colorado Region and steps must be taken to correct these problems. Damages have and will continue to increase due to the recent and expected future population increases and continued urban development in the flood plains. Also, as a result of more intensive use, the agricultural areas in the region are subject to greater damage from flooding. Average annual flood damages in the region, based on 1965 conditions and prices, is about $2.8 million. Without additional flood damage reduction measures, this damage is estimated to increase to approximately $4.2 million by 1980, $6.8 million by 2000, and $10.6 million by 2020.

In addition to economic considerations, the potential danger to life is present from rampaging rivers and streams. Appropriate and timely action should be initiated to reduce this threat to human life and excessive losses from floods.

Complete flood protection is an unrealistic goal due to the cost of protection in comparison to losses prevented and other constraints such as the need or desire to use land and water resources for purposes other than flood control. The only positive way to eliminate all flood damage is either through the use of structural measures to provide protection from the maximum possible flood on all streams, or the denial of the use of all flood plains to the extent of the maximum possible flood for all purposes. Obviously, neither of these alternatives is acceptable. An appropriate degree of protection or flood damage reduction should be provided, through structural and non-structural measures, consistent with other uses of the water and land resources. In general, it is suggested that flood protection from at least a once-in-10-year flood should be given to agricultural areas and protection from the once-in-100-year up to the standard project flood should be provided for urban areas. Implementation of the flood damage reduction program as presented would reduce the projected flood damages to $3.3 million by 1980, to $3.4 million by 2000, and to $3.8 million by 2020.

Suggestions

It is suggested that the future flood damage reduction plan contained in this appendix be adopted as a general guide for solving the flood problems of the region. The proposed possible solutions to the serious flood problems should be studied in detail and followed by timely implementation of appropriate damage reduction measures. In view of the threat to life and the increasing level of flood damage, which is projected to

increase nearly fourfold by 2020, necessary steps should be taken to assure the implementation of the early action phase (1966-1980 measures) of the future flood control program.

Some of the structural and non-structural measures in the early action phase of the plan are currently in the process of implementation; some have been authorized for implementation; and some are in the late planning stages. Planning, authorization, and funding procedures should be reviewed to insure that these measures are effective when needed. Other suggestions are as follows:

a. Sound land use planning to guide development and use of flood plains is an important means of minimizing flood losses. Existing authorities, laws, and regulations concerning zoning, subdivision regulations, building codes, and other land use constraints should be examined to determine their adequacy and possible need for change. Studies should also be made to determine the degree to which Federal, state, and local government levels should participate in the implementation and enforcement of such constraints.

b. Planning for structural flood control measures to allow prudent use of the flood plains should include investigation of potential enhancements for recreation uses, improved access, and aesthetic qualities to provide the best use of the environmental resources for the greatest number of people.

c. Steps should be taken to encourage greater participation by the general public in the initial investigation and planning of flood damage reduction programs in order to obtain a better evaluation of the tangible and intangible effects of proposed programs.

d. Adequate planning for flood damage reduction is hampered in many areas by lack of hydrological data. Additional data are needed for the study and definition of frequency, area, and duration of localized cloudburst-type floods. Implementation of non-structural flood plain management practices and the flood insurance program requires additional hydrologic data to better determine areas and frequency of inundation.

e. Current studies and research in flood forecasting and weather modification fields should be expanded, together with appropriate training of "users," so that more effective use may be made of the forecasts.

EXPLANATION OF TABLES

The tables in this appendix present data concerning past, present (1965), and projected future flood problems in the Upper Colorado Region. A brief explanation of the tables is as follows:

Table 1 - A tabulation of peak flows and flood damages for selected historical floods. Flood damages are for the entire study area.

Table 2 - A tabulation of data on the effects (damage reduction) 1965 projects had on the historical flood damage shown in Table 1.

Table 3 - A tabulation of estimated damages that would be expected on certain streams by a large flood (one occurrence in 100 years on the average) if the economic development were the same as in 1965.

Table 4 - A tabulation of average annual flood damages to selected classifications of property on representative streams in the region. Data for small tributaries and upstream watershed areas are covered under "Misc. Streams".

Table 5 - A tabulation of average annual flood damage in 1965 and at future target dates. Future damage was obtained by multiplying the 1965 damage by an appropriate development factor.

Table 6 - A tabulation of the flood control capacity of reservoirs in existence in 1965 and of those proposed for the target years.

Table 7 - A tabulation of data concerning levee and channel improvements in 1965 and in the proposed plan for the target years.

Table 8 - This table indicates the following for the region:

- Col. 2 - Flood damage under 1965 economic and project conditions--from Table 4.
- Col. 3 - Flood damage in col. 2 projected to 1980 economic conditions.
- Col. 4 - Reduction in flood damage in col. 3 credited to the 1966-1980, flood control programs.
- Col. 5 - Damages remaining in 1980 with the 1966-1980 flood control program in operation.
- Col. 6 - Flood damages under 2000 economic conditions with the 1966-1980 program in operation. Values were obtained by multiplying col. 5 by a development factor based on projected economic growth.
- Col. 7 - Reduction in damages credited to the flood control program proposed for period 1981 to 2000.
- Col. 8 - Flood damages remaining in 2000 with the 1981-2000 flood control program in operation.
- Col. 9 - Flood damages in year 2020 with 1981-2000 flood control program in operation. Values were obtained by multiplying col. 8 by a development factor based on projected economic growth.
- Col. 10 - Damage reduction credited to the 2001-2020 flood control program.
- Col. 11 - Damages remaining with 2001-2020 program in operation. Since the programs in each time frame reduce only the residual damages, at the end of the time frame, the values in col. 11 represent damages remaining after all time frame programs are in operation.

Table 9 - A tabulation of flood damage at urban areas in the region.

Table 9a - A tabulation of urban area damage projected to target years.

Table 9b - This table concerns flood damage in urban areas and is similar to Table 8. The discussions of Table 8 apply to Table 9b.

Tables 10, 10a & 10b - A tabulation of estimated costs of the flood control programs, proposed for the period 1966-1980, 1981-2000 and 2001-2020, respectively.

Table 11 - A tabulation of data concerning the maximum floods of record, standard project floods, and 100-year floods, on selected streams, including estimates of the reductions in the flow of these floods credited to the proposed flood control program.

TABLE I

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Historical Flood Data

Study area/ stream	Date of Flood	Location/ flow (cfs)	Area inundated (1,000 acres)	Flood damages 1/ - ($1,000) Forest & range resources	Forest & range facilities	Crop & pasture	Other agricul-tural	Land	Residential & commercial	Industrial & utility	Public facilities	Total
1	2	3	4	5	6	7	8	9	10	11	12	13
Duchesne River Basin												
Duchesne River	7Jun52	Duchesne, Utah 4,240	1.5	-	-	35	23	10	15	-	20	103
Strawberry, Uinta, & Lake Fork Rivers & other tributaries	7Jun52	Near Neola, Utah 2,110	3.5	-	-	147	115	25	10	-	-	297
Price River Basin												
Price River	26Apr52	Near Heiner, Utah 2,620	-	-	-	25	25	10	-	-	60	120
Price River	24Jun17	Near Helper, Utah 7,300	-	-	-	-	-	-	-	380	-	380
White River Basin												
White River	11Feb62	Near Watson, Utah 2,000	1.0	-	-	15	10	3	36	3	3	70
Blacks Fork River Basin												
Blacks & Smith Forks	11Jun65	Near Lyman, Wyoming 7,960	-	-	-	75	148	30	14	41	75	383
Yampa River Basin												
Fortification Creek	19Mar47	Craig, Colorado 841	0.5	0	0	5	2	5	10	0	15	37
Yampa River	6Jun52	Near Maybell, Colorado 13,800	3.0	-	-	-	-	24	14	100	40	178
Green River Basin												
Killpecker & Bitter Creeks	11Jul37	Rock Springs, Wyoming 9,900	-	-	-	-	-	-	37	161	60	258
Killpecker & Bitter Creeks	Aug30	Rock Springs, Wyoming 6,000	-	-	-	-	-	-	-	200	25	225
Sheep Creek	9Jun65	Near Manila, Utah 2,620	-	3	2	4	11	14	-	1	767	802
Green River	16Jun57	Near Jensen, Utah 36,500	6.0	-	-	108	40	7	-	-	-	155

1/ Data based on prices and project and economic conditions at time of occurrence of flood.

BEST AVAILABLE COPY

PRECEDING PAGE BLANK-NOT FILMED

TABLE 2

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Flood Damage 1/

Study area/	Flood	Location/ flow (cfs)	Total damages - ($1,000): At time of flood 2/: Actual damage	At time of flood 2/: Damage without flood control projects	At time of flood 2/: Damage prevented by flood control projects 4/	1965 economic conditions & prices 3/: Damage with 1965 project conditions	1965 economic conditions & prices 3/: Damage without flood control projects	1965 economic conditions & prices 3/: Damage prevented by 1965 projects 5/
1	2	3	4	5	6	7	8	9
Duchesne River Basin								
Duchesne River	7Jun52	Duchesne, Utah 4,240	103	103	0	168	168	0
Strawberry, Uinta, & Lake Fork Rivers & other tributaries	7Jun52	Near Neola, Utah 2,110	297	297	0	435	435	0
Price River Basin								
Price River	26Apr52	Near Heiner, Utah 2,620	120	120	0	168	168	0
White River Basin								
White River	11Feb62	Near Watson, Utah 2,000	70	70	0	77	77	0
Blacks Fork River Basin								
Blacks & Smith Forks	11Jun65	Near Lyman, Wyoming 7,960	383	383	0	383	383	0
Yampa River Basin								
Fortification Creek	19Mar47	Craig, Colorado 841	37	37	0	125	125	0
Yampa River	6Jun52	Near Maybell, Colorado 13,800	178	178	0	265	265	0
Green River Basin								
Killpecker & Bitter Creeks	11Jul37	Rock Springs, Wyoming 9,900	258	258	0	1,395	1,395	0
Sheep Creek	9Jun65	Near Manila, Utah 2,620	802	802	0	802	802	0
Green River	16Jun57	Near Jensen, Utah 36,500	155	155	0	198	198	0

1/ Maximum floods for which data are available.
2/ Data based on prices and project and economic conditions at time of occurrence of flood.
3/ Data based on recurrence of original flood.
4/ Column 6 = column 5 - column 4.
5/ Column 9 = column 8 - column 7.

TABLE 3

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Flood Damage for the 100-Year Frequency Flood 1/ for Selected Streams

Study area/ stream	Area inundated (acres)	Flood damage 2/ - ($1,000): Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utilities	Public facilities	Total
1	2	3	4	5	6	7	8	9	10	11
Duchesne River Basin										
Duchesne River	8,500	0	0	70	60	30	118	25	175	478
Price River Basin										
Price River	6,100	0	0	70	45	26	200	102	218	661
White River Basin										
White River	12,000	8	0	150	60	52	158	65	185	678
Blacks Fork River Basin										
Blacks & Smith Forks	4,500	7	0	90	40	39	65	19	98	358
Yampa River Basin										
Yampa River	16,000	0	0	105	48	35	125	35	165	513
Green River Basin										
Green River	18,000	20	0	115	65	88	150	40	[illegible]	703

1/ See Table 11 for magnitude of 100-year flood at selected stations.
2/ Based on July 1965 prices, economic and project conditions.

BEST AVAILABLE COPY

TABLE 4

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage

Study area (principal stream)	Flood damage 1/ - ($1,000) Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utilities	Public facilities	Study area totals
1	2	3	4	5	6	7	8	9	10
Duchesne River Basin	6	3	28	7	16	17	3	53	133
Duchesne River	(0)	(0)	(8)	(3)	(2)	(10)	(3)	(16)	(42)
Uinta & Whiterocks Rivers	(0)	(0)	(8)	(1)	(2)	(3)	(0)	(10)	(24)
Strawberry River	(0)	(0)	(1)	(0)	(1)	(2)	(0)	(3)	(7)
Lake Fork	(0)	(0)	(3)	(1)	(1)	(0)	(0)	(6)	(11)
Miscellaneous streams	(6)	(3)	(8)	(2)	(10)	(2)	(0)	(18)	(49)
Price River Basin	4	2	64	11	39	17	7	27	171
Price River	(0)	(0)	(10)	(2)	(4)	(14)	(6)	(13)	(49)
Miscellaneous streams	(4)	(2)	(54)	(9)	(35)	(3)	(1)	(14)	(122)
White River Basin	6	2	44	6	11	9	4	26	108
White River	(2)	(0)	(26)	(4)	(6)	(8)	(3)	(13)	(62)
Miscellaneous streams	(4)	(2)	(18)	(2)	(5)	(1)	(1)	(13)	(46)
San Rafael River Basin	3	1	64	11	35	8	2	20	144
Blacks Fork River Basin	1	0	20	2	6	4	2	13	48
Blacks & Smith Forks	(1)	(0)	(18)	(2)	(5)	(3)	(1)	(8)	(38)
Miscellaneous streams	(0)	(0)	(2)	(0)	(1)	(1)	(1)	(5)	(10)
Yampa River Basin	4	2	32	9	25	29	6	38	145
Yampa River	(0)	(0)	(12)	(6)	(3)	(12)	(3)	(10)	(46)
Fortification Creek	(0)	(0)	(7)	(2)	(2)	(15)	(3)	(10)	(39)
Miscellaneous streams	(4)	(2)	(13)	(1)	(20)	(2)	(0)	(18)	(60)
Green River Basin 2/	14	3	73	13	32	38	16	60	249
Green River	(3)	(0)	(15)	(5)	(9)	(13)	(6)	(12)	(63)
Bitter Creek	(0)	(0)	(4)	(1)	(3)	(15)	(6)	(18)	(47)
Ashley Creek	(0)	(0)	(10)	(2)	(2)	(7)	(2)	(10)	(33)
Miscellaneous streams	(11)	(3)	(44)	(5)	(18)	(3)	(2)	(20)	(106)
Subregion Totals	38	13	325	59	164	122	40	237	998

1/ Damages based on July 1965 prices, economic and project conditions.
2/ Includes data for the New Fork River Basin, Big Sandy Creek Basin, Willow Creek Basin, Vermilion River Basin, and Green River Basin.

TABLE 5

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Summary of Estimated Average Annual Flood Damage for Present
and Future Conditions of Economic Development
with Existing Flood Control Measures

Study area (principal stream)	Average annual flood damages 1/ - ($1,000) 1965 economic conditions 2/	1980 economic conditions	2000 economic conditions	2020 economic conditions
1	2	3	4	5
Duchesne River Basin	133	197	317	468
Duchesne River	(42)	(63)	(111)	(170)
Uinta & Whiterocks Rivers	(24)	(37)	(59)	(80)
Strawberry River	(7)	(11)	(20)	(36)
Lake Fork	(11)	(18)	(26)	(34)
Miscellaneous streams	(49)	(68)	(101)	(148)
Price River Basin	171	232	345	576
Price River	(49)	(73)	(120)	(221)
Miscellaneous streams	(122)	(159)	(225)	(355)
White River Basin	108	164	264	417
White River	(62)	(103)	(178)	(289)
Miscellaneous streams	(46)	(61)	(86)	(128)
San Rafael River Basin	144	205	310	456
Blacks Fork River Basin	48	70	103	149
Blacks & Smith Forks	(38)	(55)	(82)	(121)
Miscellaneous streams	(10)	(15)	(21)	(28)
Yampa River Basin	145	225	358	537
Yampa River	(46)	(72)	(123)	(180)
Fortification Creek	(39)	(74)	(130)	(199)
Miscellaneous streams	(60)	(79)	(105)	(158)
Green River Basin	249	376	609	955
Green River	(63)	(95)	(155)	(230)
Bitter Creek	(47)	(75)	(140)	(248)
Ashley Creek	(33)	(51)	(89)	(169)
Miscellaneous streams	(106)	(155)	(225)	(308)
Subregion Totals	998	1,469	2,306	3,558

1/ Damages based on July 1965 prices and project conditions, and estimated economic conditions for the year shown.
2/ Figures in column 2 are from column 10, "Total," shown on Table 4.

TABLE 6

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Summary of Flood Control Capacity for Existing and Future Reservoirs

Study area	Flood control capacity 1/ - (1,000 ac-ft)				
	Existing projects (1965)	Projects 1966-1980	Projects 1981-2000	Projects 2001-2020	Total projects as of 2020
1	2	3	4	5	6
Duchesne River Basin	0	213	69	3	285
Uinta & Whiterocks Rivers	(0)	(61)	(0)	(0)	(61)
Strawberry River	(0)	(152)	(0)	(0)	(152)
Lake Fork River	(0)	(0)	(66)	(0)	(66)
Miscellaneous streams	(0)	(0)	(3)	(3)	(6)
Price River Basin	0	0	6	2	8
Miscellaneous streams	(0)	(0)	(6)	(2)	(8)
White River Basin		0	39	25	64
White River	(0)	(0)	(17)	(0)	(17)
Miscellaneous streams	(0)	(0)	(22)	(25)	(47)
San Rafael River Basin	0	6	0	6	12
Blacks Fork River Basin	0	30	0	0	30
Blacks & Smith Forks	(0)	(30)	(0)	(0)	(30)
Yampa River Basin	0	73	11	50	134
Fortification Creek	(0)	(0)	(5)	(0)	(5)
Miscellaneous streams	(0)	(73)	(6)	(50)	(129)
Green River Basin	0	165	44	17	226
Green River	(0)	(150)	(0)	(0)	(150)
Bitter Creek	(0)	(0)	(11)	(0)	(11)
Ashley Creek	(0)	(13)	(0)	(0)	(13)
Miscellaneous streams	(0)	(2)	(33)	(17)	(52)
Subregion Totals	0	487	169	103	759

1/ Maximum flood control capacity. Does not include surcharge storage.

TABLE 7

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Summary of Levee and Channel Flood Protection Projects
- Existing and Future -

Study area	Levee and channel projects									
	Existing projects (1965)		Projects 1966-1980		Projects 1981-2000		Projects 2001-2020		Total project as of 2020	
	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)
1	2	3	4	5	6	7	8	9	10	11
Duchesne River Basin										
Duchesne River	0	0	0	0	1.0	0	0	0	1.0	0
Yampa River Basin										
Fortification Creek	0	0	0	0	2.4	1.6	0	0	2.4	1.6
Green River Basin										
Bitter Creek	0	0	0	0	2.0	2.0	0	0	2.0	2.0
Subregion Totals	0	0	0	0	5.4	3.6	0	0	5.4	3.6

TABLE 8

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage and Damage Reduction
- Present and Future Economic Conditions -

Study area (principal stream)	Total damages - 1965 prices ($1,000)									
	1965 economic & project conditions 1/	1980 economic conditions			2000 economic conditions			2020 economic conditions		
		W/1965 program conditions 2/	Reduction in damages due to 1980 flood control program 3/	Residual damage w/1980 program 4/	W/1980 program conditions	Reduction in damages due to 2000 flood control program 3/	Residual damage w/2000 program 5/	W/2000 program conditions	Reduction in damages due to 2020 flood control program 3/	Residual damage w/2020 program 6/
1	2	3	4	5	6	7	8	9	10	11
Duchesne River Basin	133	197	64	133	222	82	140	211	35	176
Duchesne River	(42)	(63)	(13)	(50)	(88)	(33)	(55)	(79)	(0)	(79)
Uinta & Whiterocks Rivers	(24)	(37)	(29)	(8)	(15)	(0)	(15)	(26)	(0)	(26)
Strawberry River	(7)	(11)	(4)	(7)	(13)	(0)	(13)	(22)	(0)	(22)
Lake Fork	(11)	(18)	(0)	(18)	(26)	(19)	(7)	(13)	(0)	(13)
Miscellaneous streams	(49)	(68)	(18)	(50)	(80)	(30)	(50)	(71)	(35)	(36)
Price River Basin	171	232	22	210	302	120	182	301	30	271
Price River	(49)	(73)	(0)	(73)	(120)	(50)	(70)	(126)	(0)	(126)
Miscellaneous streams	(122)	(159)	(22)	(137)	(182)	(70)	(112)	(175)	(30)	(145)
White River Basin	108	164	5	159	256	35	221	341	91	250
White River	(62)	(103)	(0)	(103)	(178)	(35)	(143)	(230)	(76)	(154)
Miscellaneous streams	(46)	(61)	(5)	(56)	(78)	(0)	(78)	(111)	(15)	(96)
San Rafael River Basin	144	205	47	158	223	0	223	286	60	226
Blacks Fork River Basin	48	70	12	58	79	0	79	109	8	101
Blacks & Smith Forks	(38)	(55)	(12)	(43)	(58)	(0)	(58)	(81)	(0)	(81)
Miscellaneous streams	(10)	(15)	(0)	(15)	(21)	(0)	(21)	(28)	(8)	(20)
Yampa River Basin	145	225	39	186	305	117	188	269	100	169
Yampa River	(46)	(72)	(0)	(72)	(123)	(0)	(123)	(180)	(85)	(95)
Fortification Creek	(39)	(74)	(0)	(74)	(130)	(92)	(38)	(49)	(0)	(49)
Miscellaneous streams	(60)	(79)	(39)	(40)	(52)	(25)	(27)	(40)	(15)	(25)
Green River Basin	249	376	113	263	410	190	220	325	75	250
Green River	(63)	(95)	(38)	(57)	(85)	(0)	(85)	(119)	(0)	(119)
Bitter Creek	(47)	(75)	(0)	(75)	(140)	(115)	(25)	(41)	(10)	(31)
Ashley Creek	(33)	(51)	(29)	(22)	(35)	(0)	(35)	(63)	(0)	(63)
Miscellaneous streams	(106)	(155)	(46)	(109)	(150)	(75)	(75)	(102)	(65)	(37)
Subregion Totals	998	1,469	302	1,167	1,797	544	1,253	1,842	399	1,443

1/ Figures shown in Column 2 are from "Total" Column of Table 4 and are also shown in Column 2 of Table 5.
2/ Figures in Column 3 are from Column 3 of Table 5.
3/ Includes structural and non-structural measures.
4/ Column 5 = Column 3 - Column 4.
5/ Column 8 = Column 6 - Column 7.
6/ Column 11 = Column 9 - Column 10.

TABLE 9

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage for Urban
Areas with Significant Flood Problems

Study area/ stream	Damage center	Average annual flood damages ($1,000) 1/				
		Residential	Commercial	Industrial & utilities	Public facilities	Total
1	2	3	4	5	6	7
Duchesne River Basin						
Duchesne-Strawberry Rivers	Duchesne, Utah	5	3	1	9	18
Price River Basin						
Price River-Willow Creek	Price, Castlegate & Helper, Utah	8	3	5	9	25
White River Basin						
White River	Rangely, Colorado	3	1	2	6	12
Yampa River Basin						
Fortification Creek-Yampa River	Craig, Colorado	8	7	3	8	26
Green River Basin						
Green River	Green River, Wyoming	6	2	3	3	14
Killpecker & Bitter Creeks	Rock Springs, Wyoming	9	9	6	13	37
Ashley Creek	Vernal, Utah	4	3	2	8	17
Subregion Totals		43	28	22	56	149

1/ Damages are based on July 1965 prices, economic and project conditions.

TABLE 9a

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Summary of Estimated Average Annual Flood Damage for Urban Areas with Significant Flood Problems
- Present and Future Conditions of Economic Development
with Existing Flood Control Measures -

Study area/ stream	Damage center	Average annual flood damages 1/ - ($1,000) 1965 economic conditions 2/	1980 economic conditions	2000 economic conditions	2020 economic conditions
1	2	3	4	5	6
Duchesne River Basin					
Duchesne & Strawberry Rivers	Duchesne, Utah	18	29	57	125
Price River Basin					
Price River-Willow Creek	Price, Castlegate & Helper, Utah	25	49	98	190
White River Basin					
White River	Rangely, Colorado	12	20	38	74
Yampa River Basin					
Fortification Creek-Yampa River	Craig, Colorado	26	46	88	204
Green River Basin					
Green River	Green River, Wyoming	14	29	56	112
Killpecker & Bitter Creeks	Rock Springs, Wyoming	37	72	135	262
Ashley Creek	Vernal, Utah	17	33	66	132
Subregion Totals		149	278	538	1,099

1/ Damages based on July 1965 prices and project conditions, and estimated economic conditions for the year shown.
2/ Figures in Column 3 are from Column 7, "Total", shown on Table 9.

TABLE 9b

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage and Damage Reduction
for Urban Areas with Significant Flood Problems
- Present and Future Economic Conditions -

Study area/ stream	Damage center	Total damages - 1965 prices ($1,000) 1965 economic & project conditions 1/	1980 economic conditions W/1965 program 2/	Reduction due to 1980 program: Non-structural measures	Structural measures	Residual damage w/1980 program 3/	2000 economic conditions W/1980 program	Reduction due to 2000 program: Non-structural measures	Structural measures	Residual damage w/2000 program 4/	2020 economic conditions W/2000 program	Reduction due to 2020 program: Non-structural measures	Structural measures	Residual damage w/2020 program 5/
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Duchesne River Basin														
Duchesne & Strawberry Rivers	Duchesne, Utah	18	29	0	4	25	49	0	33	16	26	0	0	26
Price River Basin														
Willow Creek Price River	Helper, Castlegate & Price Utah	25	49	0	0	49	98	50	18	30	52	0	0	52
White River Basin														
White River	Rangely, Colorado	12	20	0	0	20	38	0	5	33	67	0	10	57
Yampa River Basin														
Fortification Creek-Yampa River	Craig, Colorado	26	46	0	0	46	88	0	65	23	44	0	10	34
Green River Basin														
Green River	Green River, Wyoming	14	29	0	23	6	12	0	0	12	23	0	0	23
Killpecker & Bitter Creeks	Rock Springs, Wyoming	37	72	0	0	72	135	0	115	20	38	0	6	32
Ashley Creek	Vernal, Utah	17	33	0	17	16	25	0	0	25	52	0	0	52
Subregion Totals		149	278	0	44	234	445	50	236	159	302	0	26	276

1/ Figures shown in column 3 are from "Total" column of Table 9 and are also shown in column 3 of Table 9a.
2/ Figures in column 4 are from column 4 of Table 9a.
3/ Column 7 = column 4 - column 5 - column 6.
4/ Column 11 = column 8 - column 9 - column 10.
5/ Column 15 = column 12 - column 13 - column 14.

TABLE 10

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 1966 to 1980 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Duchesne River Basin	0	0	0	0	420	2	0	0	190	45	0	0
Price River Basin	0	0	0	0	0	0	0	0	0	0	0	0
White River Basin	0	0	0	0	0	0	0	0	0	0	0	0
San Rafael River Basin	0	0	0	0	1,200	0	430	3	0	0	0	0
Blacks Fork River Basin	0	0	0	0	200	5	0	0	0	0	0	0
Yampa River Basin	0	0	0	0	700	8	0	0	0	0	0	0
Green River Basin	0	0	0	0	2,410	2	40	63	0	0	0	0
Subregion Totals	0	0	0	0	4,930	17	470	66	190	45	0	0

1/ Costs of watershed treatment measures are not included.

TABLE 10a

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 1981 to 2000 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Duchesne River Basin	300	0	100	3	540	2	60	2	30	22	0	0
Price River Basin	0	0	0	0	320	0	80	4	30	0	970	9
White River Basin	0	0	0	0	420	2	0	0	0	0	0	0
San Rafael River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Blacks Fork River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Yampa River Basin	300	0	100	3	1,280	0	320	7	0	0	0	0
Green River Basin	1,000	0	400	7	3,580	1	820	18	0	0	0	0
Subregion Totals	1,600	0	600	13	6,140	5	1,280	31	60	22	970	9

1/ Costs of watershed treatment measures are not included.

TABLE 10b

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 2001 to 2020 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Duchesne River Basin	0	0	0	0	170	0	30	2	10	4	0	0
Price River Basin	0	0	0	0	80	0	20	1	0	0	0	0
White River Basin	0	0	0	0	800	6	0	0	0	0	0	0
San Rafael River Basin	0	0	0	0	850	0	150	5	0	0	0	0
Blacks Fork River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Yampa River Basin	0	0	0	0	1,500	8	0	0	0	0	0	0
Green River Basin	0	0	0	0	2,120	0	370	9	0	0	0	0
Subregion Totals	0	0	0	0	5,520	14	570	17	10	4	0	0

1/ Costs of watershed treatment measures are not included.

TABLE 11

GREEN RIVER SUBREGION OF THE UPPER COLORADO REGION

Flow Data at Selected Locations
(Flows in 1,000 cfs)

Study area/ stream	Location of stream gage	Non-damaging flow 1/	Maximum flood of record						Flow of standard project flood				Flow of 100-year frequency flood			
			Date	Flow												
				At time of occurrence	Existing (1965) project conditions	Future project conditions 2/			Existing (1965) project conditions	Future project conditions 2/			Existing (1965) project conditions	Future project conditions 2/		
						1980	2000	2020		1980	2000	2020		1980	2000	2020
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Duchesne River Basin																
Duchesne River	Duchesne, Utah	2.6	10Jun22	4.4	4.4	4.4	4.4	4.4	6.4	6.4	6.4	6.4	5.0	5.0	5.0	5.0
Uinta River	Neola, Utah	1.6	26Jun44	3.3	3.3	1.6	1.6	1.6	14.0	9.0	9.0	9.0	5.0	2.5	2.5	2.5
Whiterocks River	Whiterocks, Utah	1.4	18Jun49	1.8	1.8	1.4	1.4	1.4	13.0	9.0	9.0	9.0	4.3	2.6	2.6	2.6
Strawberry River	Duchesne, Utah	2.2	7May52	3.5	3.5	2.2	2.2	2.2	7.4	5.5	5.5	5.5	4.4	2.9	2.9	2.9
Lake Fork	Myton, Utah	1.8	10Sep27	4.6	4.6	4.6	2.5	2.5	12.7	12.7	11.2	11.2	8.7	8.7	5.8	5.8
Price River Basin																
Price River	Heiner, Utah	2.0	13Sep40	9.3	9.3	9.3	9.3	9.3	30.0	30.0	30.0	30.0	12.5	12.5	12.5	12.5
White River Basin																
White River	Meeker, Colorado	3.5	16Jun21	6.4	6.4	6.4	4.3	3.5	17.0	17.0	10.0	8.0	8.5	8.5	5.5	4.5
San Rafael River Basin																
San Rafael River	Near Green River, Utah	4.0	25Sep09	12.0	12.0	12.0	12.0	12.0	30.0	30.0	30.0	30.0	18.0	18.0	18.0	18.0
Blacks Fork River Basin																
Blacks Fork	Urie, Wyoming	1.5	19Jun17	2.7	2.7	2.0	2.0	2.0	19.0	8.0	8.0	8.0	6.2	3.5	3.5	3.5
Smith Fork	Mountain View, Wyoming	0.9	13Jun53	1.1	1.1	1.1	1.1	1.1	10.0	10.0	10.0	10.0	3.3	3.3	3.3	3.3
Yampa River Basin																
Yampa River	Maybell, Colorado	9.0	19May17	17.9	17.9	17.9	17.9	15.0	42.0	42.0	42.0	38.0	21.0	21.0	21.0	16.0
Fortification Creek	Craig, Colorado	0.5	23Jun47	0.8	0.8	0.8	0.5	0.5	4.5	4.5	3.0	3.0	2.6	2.6	1.5	1.5
Green River Basin																
Green River	Green River, Wyoming	15.0	19Jun18	22.2	22.2	11.0	11.0	11.0	30.0	15.0	15.0	15.0	24.0	11.0	11.0	11.0
Bitter Creek	Rock Springs, Wyoming	5.0	(Ungaged)						16.0	16.0	14.0	12.5	11.0	11.0	8.0	7.0
Ashley Creek	Vernal, Utah	0.7	13May41	1.4	1.4	1.0	1.0	1.0	12.0	9.6	9.6	9.6	4.4	2.5	2.5	2.5

1/ Under 1965 project conditions.
2/ Flows as modified by projects likely to be in a future flood control program by the years 1980, 2000, and 2020.

TABLE 1

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Historical Flood Data

Study area	Flood	Location/ flow (cfs)	Area inundated (1,000 acres)	Flood damages 1/ - ($1,000): Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utility	Public facilities	Total
1	2	3	4	5	6	7	8	9	10	11	12	13
Roaring Fork River Basin												
Roaring Fork	1Jul57	Glenwood Springs 19,000	-	-	-	6	1	6	2	-	20	35
Gunnison River Basin												
Gunnison River	6Jun57	Near Grand Junction 27,800	2.4	-	-	34	29	19	45	16	96	239
North Fork - Gunnison River	4Jun57	Somerset 7,860	0.3	-	-	40	8	10	-	3	26	87
Portland - Cascade Creeks	11Jul65	Ouray 8,085	-	-	-	-	-	-	130	20	50	200
Dolores River Basin												
Dolores River	14May41	Dolores 8,070	-	-	-	2	-	4	2	28	11	47
Dolores River	21Apr58	Gateway 16,700	1.1	-	-	49	1	8	51	2	118	229
Dolores River	6Jun57	Dolores 6,690	-	-	-	8	1	2	1	-	55	67
Colorado River Basin												
Colorado River	9Jun52	Near Colorado-Utah line 52,000	1.1	-	-	-	1	13	6	45	4	69
Colorado River	9Jun57	Near Colorado-Utah line 56,800	1.5	-	-	20	17	25	3	-	127	192
Mill & Pack Creeks	26Aug61	Near Moab 5,100	-	-	-	3	1	2	8	-	38	52
Indian Wash	6Jun58	Near Highline Canal 2,700	0.2	-	-	1	-	-	14	-	11	26

1/ Data based on prices and project and economic conditions at time of occurrence of flood.

TABLE 2

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Flood Damage 1/

Study area	Flood	Location/ flow (cfs)	Total damages - ($1,000): At time of flood 2/: Actual damage	Damage without flood control projects	Damage prevented by flood control projects 4/	1965 economic conditions & prices 3/: Damage with 1965 project conditions	Damage without flood control projects	Damage prevented by 1965 projects 5/
1	2	3	4	5	6	7	8	9
Roaring Fork River Basin								
Roaring Fork	1Jul57	Glenwood Springs 19,000	35	35	0	40	40	0
Gunnison River Basin								
Gunnison River	6Jun57	Near Grand Junction 27,800	239	239	0	288	288	0
North Fork - Gunnison River	4Jun57	Somerset 7,860	87	87	0	83	100	17
Portland & Cascade Creeks	11Jul65	Ouray 8,085	200	200	0	200	200	0
Dolores River Basin								
Dolores River	14May41	Dolores 8,070	47	47	0	149	149	0
Dolores River	21Apr58	Gateway 16,700	229	229	0	254	254	0
Dolores River	6Jun57	Dolores 6,690	67	67	0	87	87	0
Colorado River Basin								
Colorado River	9Jun52	Near Colorado-Utah line 52,000	69	69	0	99	99	0
Colorado River	9Jun57	Near Colorado-Utah line 56,800	192	192	0	228	228	0
Mill & Pack Creeks	26Aug61	Near Moab 5,100	52	52	0	56	56	0
Indian Wash	6Jun58	Near Highline Canal 2,700	26	26	0	8	30	22

1/ Maximum floods for which data are available.
2/ Data based on prices and project and economic conditions at time of occurrence of flood.
3/ Data based on recurrence of original flood.
4/ Column 6 = Column 5 - Column 4.
5/ Column 9 = Column 8 - Column 7.

TABLE 3

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Flood Damage for
the 100-Year Frequency Flood 1/
for Selected Streams

Study area/ stream	Area inundated (acres)	Flood damage 2/ - ($1,000) Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utilities	Public facilities	Total
1	2	3	4	5	6	7	8	9	10	11
Roaring Fork River Basin										
Crystal River	600	0	25	9	5	15	20	4	37	115
Gunnison River Basin										
Gunnison River	3,500	0	0	160	40	35	357	105	587	1,284
Dolores River Basin										
Dolores River	8,700	0	0	120	29	53	503	106	559	1,372
Colorado River Basin										
Colorado River	14,500	0	0	153	80	75	285	90	899	1,582

1/ See Table 11 for magnitude of 100-year flood at selected stations.
2/ Based on July 1965 prices, economic and project conditions.

TABLE 4

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage

Study area (principal stream)	Flood damage 1/ - ($1,000) Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utilities	Public facilities	Study area totals
1	2	3	4	5	6	7	8	9	10
Roaring Fork River Basin	5	7	9	3	8	7	2	20	61
Roaring Fork	(0)	(0)	(4)	(1)	(2)	(3)	(0)	(5)	(15)
Crystal River	(0)	(1)	(2)	(1)	(1)	(3)	(1)	(7)	(16)
Miscellaneous Streams	(5)	(6)	(3)	(1)	(5)	(1)	(1)	(8)	(30)
Gunnison River Basin	26	15	176	24	30	53	19	81	424
Gunnison River	(0)	(0)	(20)	(3)	(7)	(29)	(9)	(39)	(107)
Uncompahgre River	(0)	(0)	(8)	(1)	(2)	(4)	(1)	(6)	(22)
North Fork-Gunnison River	(0)	(0)	(4)	(1)	(1)	(2)	(1)	(4)	(13)
Miscellaneous Streams	(26)	(15)	(144)	(19)	(20)	(18)	(8)	(32)	(282)
Dolores River Basin	10	3	48	4	21	73	24	70	253
Dolores River	(0)	(0)	(14)	(1)	(8)	(39)	(10)	(45)	(117)
San Miguel River	(0)	(0)	(1)	(0)	(3)	(25)	(13)	(10)	(52)
Miscellaneous Streams	(10)	(3)	(33)	(3)	(10)	(9)	(1)	(15)	(84)
Colorado River Basin	10	10	42	12	36	82	15	88	295
Colorado River	(0)	(0)	(10)	(7)	(15)	(17)	(6)	(44)	(99)
Mill & Pack Creeks	(2)	(1)	(3)	(1)	(2)	(40)	(5)	(20)	(74)
Miscellaneous Streams	(8)	(9)	(29)	(4)	(19)	(25)	(4)	(24)	(122)
Eagle River Basin	4	6	8	1	8	2	4	10	43
Subregion Totals	55	41	283	44	103	217	64	269	1,076

1/ Damages based on July 1965 prices, economic and project conditions.

TABLE 5

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Summary of Estimated Average Annual Flood Damage for Present and Future Conditions of Economic Development with Existing Flood Control Measures

Study area (principal stream)	Average annual flood damages 1/ - ($1,000)			
	1965 economic conditions 2/	1980 economic conditions	2000 economic conditions	2020 economic conditions
1	2	3	4	5
Roaring Fork River Basin	61	85	134	227
Roaring Fork	(15)	(22)	(37)	(68)
Crystal River	(16)	(23)	(39)	(70)
Miscellaneous streams	(30)	(40)	(58)	(89)
Gunnison River Basin	424	572	899	1,410
Gunnison River	(107)	(183)	(315)	(583)
Uncompahgre River	(22)	(34)	(58)	(92)
North Fork-Gunnison River	(13)	(20)	(36)	(53)
Miscellaneous streams	(282)	(335)	(490)	(682)
Dolores River Basin	253	372	613	903
Dolores River	(117)	(174)	(298)	(450)
San Miguel River	(52)	(82)	(140)	(205)
Miscellaneous streams	(84)	(116)	(175)	(248)
Colorado River Basin	295	500	776	1,315
Colorado River	(99)	(158)	(225)	(458)
Mill & Pack Creeks	(74)	(163)	(286)	(489)
Miscellaneous streams	(122)	(179)	(265)	(368)
Eagle River Basin	43	62	90	128
Subregion Totals	1,076	1,591	2,512	3,983

1/ Damages based on July 1965 prices and project conditions, and estimated economic conditions for the year shown.
2/ Figures in Column 2 are from Column 10, "Total", shown on Table 4.

TABLE 6

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Summary of Flood Control Capacity for Existing and Future Reservoirs

Study area	Flood control capacity 1/ - (1,000 ac-ft)				
	Existing projects (1965)	Projects 1966-1980	Projects 1981-2000	Projects 2001-2020	Total projects as of 2020
1	2	3	4	5	6
Roaring Fork River Basin	0	101	88	0	189
Crystal River	(0)	-	(88)	(0)	(88)
Miscellaneous streams	(0)	(101)	(0)	(0)	(101)
Gunnison River Basin	18	859	16	5	898
Gunnison River	(0)	(748)	(0)	(0)	(748)
Uncompahgre River	(0)	(111)	(0)	(0)	(111)
Miscellaneous streams	(18)	(0)	(16)	(5)	(39)
Dolores River Basin	0	212	66	1	279
Dolores River	(0)	(212)	(0)	(0)	(212)
San Miguel River	(0)	-	(65)	(0)	(65)
Miscellaneous streams	(0)	(0)	(1)	(1)	(2)
Colorado River Basin	1	7	141	0	149
Colorado River	(0)	(0)	(140)	(0)	(140)
Mill & Pack Creeks	(0)	(7)	(0)	(0)	(7)
Miscellaneous streams	(1)	(0)	(1)	(0)	(2)
Eagle River Basin	0	0	2	0	2
Subregion Totals	19	1,179	313	6	1,517

1/ Maximum flood control capacity. Does not include surcharge storage.

TABLE 7

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Summary of Levee and Channel Flood Protection Projects
- Existing and Future -

Study area	Levee and channel projects									
	Existing projects (1965)		Projects 1966-1980		Projects 1981-2000		Projects 2001-2020		Total project as of 2020	
	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)
1	2	3	4	5	6	7	8	9	10	11
Dolores River Basin										
Dolores River	0	0	0	0	2	0	0	0	2	0
Colorado River Basin										
Mill & Pack Creeks	0	0	0	3	0	0	0	0	0	3
Subregion Totals	0	0	0	3	2	0	0	0	2	3

TABLE 8

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage and Damage Reduction
- Present and Future Economic Conditions -

Study area (principal stream)	Total damages - 1965 prices ($1,000)									
	1965 economic	1980 economic conditions			2000 economic conditions			2020 economic conditions		
	& project conditions 1/	W/1965 program conditions 2/	Reduction in damages due to 1980 flood control program 3/	Residual damage w/1980 program 4/	W/1980 program conditions	Reduction in damages due to 2000 flood control program 3/	Residual damage w/2000 program 5/	W/2000 program conditions	Reduction in damages due to 2020 flood control program 3/	Residual damage w/2020 program 6/
1	2	3	4	5	6	7	8	9	10	11
Roaring Fork River Basin	61	85	23	62	98	26	72	114	20	94
Roaring Fork	(15)	(22)	(8)	(14)	(23)	(0)	(23)	(40)	(10)	(30)
Crystal River	(16)	(23)	(0)	(23)	(39)	(26)	(13)	(22)	(0)	(22)
Miscellaneous streams	(30)	(40)	(15)	(25)	(36)	(0)	(36)	(52)	(10)	(42)
Gunnison River Basin	424	572	159	413	628	225	403	567	125	442
Gunnison River	(107)	(183)	(115)	(68)	(119)	(25)	(94)	(165)	(50)	(115)
Uncompahgre River	(22)	(34)	(19)	(15)	(23)	(10)	(13)	(20)	(5)	(15)
North Fork-Gunnison River	(13)	(20)	(0)	(20)	(36)	(10)	(26)	(37)	(0)	(37)
Miscellaneous streams	(282)	(335)	(25)	(310)	(450)	(180)	(270)	(345)	(70)	(275)
Dolores River Basin	253	372	69	303	496	226	270	386	65	321
Dolores River	(117)	(174)	(34)	(140)	(238)	(126)	(112)	(168)	(15)	(153)
San Miguel River	(52)	(82)	(0)	(82)	(140)	(85)	(55)	(72)	(0)	(72)
Miscellaneous streams	(84)	(116)	(35)	(81)	(118)	(15)	(103)	(146)	(50)	(96)
Colorado River Basin	295	500	224	276	404	126	278	411	80	331
Colorado River	(99)	(158)	(45)	(113)	(160)	(96)	(64)	(109)	(0)	(109)
Mill & Pack Creeks	(74)	(163)	(154)	(9)	(14)	(0)	(14)	(22)	(0)	(22)
Miscellaneous streams	(122)	(179)	(25)	(154)	(230)	(30)	(200)	(280)	(80)	(200)
Eagle River Basin	43	62	10	52	78	20	58	80	10	70
Subregion Totals	1,076	1,591	485	1,106	1,704	623	1,081	1,558	300	1,258

1/ Figures shown in Column 2 are from "Total" Column of Table 4 and are also shown in Column 2 of Table 5.
2/ Figures in Column 3 are from Column 3 of Table 5.
3/ Includes structural and non-structural measures.
4/ Column 5 = Column 3 - Column 4.
5/ Column 8 = Column 6 - Column 7.
6/ Column 11 = Column 9 - Column 10.

TABLE 9

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage for Urban Areas with Significant Flood Problems

Study area/ stream	Damage center	Average annual flood damages ($1,000) 1/ Residential	Commercial	Industrial & utilities	Public facilities	Total
1	2	3	4	5	6	7
Gunnison River Basin						
Gunnison-Uncompahgre Rivers	Delta, Colorado	9	5	6	15	35
Gunnison River	Grand Junction	3	2	2	15	22
Uncompahgre River-Montrose Arroyo	Montrose	6	4	1	4	15
Dolores River Basin						
Dolores River	Dolores	11	9	8	8	36
Colorado River Basin						
Colorado River, Indian Wash	Grand Junction & Vicinity	8	5	5	12	30
Mill & Pack Creeks, Miscellaneous canyons	Moab, Utah	25	20	6	24	75
Subregion Totals		62	45	28	78	213

1/ Damages are based on July 1965 prices, economic and project conditions.

TABLE 9a

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Summary of Estimated Average Annual Flood Damage for Urban Areas with Significant Flood Problems
- Present and Future Conditions of Economic Development with Existing Flood Control Measures -

Study area/ stream	Damage center	Average annual flood damages 1/ - ($1,000) 1965 economic conditions 2/	1980 economic conditions	2000 economic conditions	2020 economic conditions
1	2	3	4	5	6
Gunnison River Basin					
Gunnison-Uncompahgre Rivers	Delta, Colorado	35	71	129	247
Gunnison River	Grand Junction	22	42	86	177
Uncompahgre River-Montrose Arroyo	Montrose	15	35	72	110
Dolores River Basin					
Dolores River	Dolores	36	69	148	272
Colorado River Basin					
Colorado River, Indian Wash	Grand Junction & Vicinity	30	58	111	228
Mill & Pack Creeks, Miscellaneous canyons	Moab, Utah	75	182	304	588
Subregion Totals		213	457	850	1,622

1/ Damages based on July 1965 prices and project conditions, and estimated economic conditions for the year shown.
2/ Figures in Column 3 are from Column 7, "Total", shown on Table 9.

BEST AVAILABLE COPY

TABLE 9b

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage and Damage Reduction
for Urban Areas with Significant Flood Problems
- Present and Future Economic Conditions -

Study area/ stream	Damage center	Total damages - 1965 prices ($1,000)												
		1965	1980 economic conditions				2000 economic conditions				2020 economic conditions			
		economic & project conditions 1/	W/1965 program 2/	Reduction due to 1980 program: Non-structural measures	Reduction due to 1980 program: Structural measures	Residual damage w/1980 program 3/	W/1980 program	Reduction due to 2000 program: Non-structural measures	Reduction due to 2000 program: Structural measures	Residual damage w/2000 program 4/	W/2000 program	Reduction due to 2020 program: Non-structural measures	Reduction due to 2020 program: Structural measures	Residual damage w/2020 program 5/
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Gunnison River Basin														
Gunnison & Uncompahgre Rivers	Delta	35	71	0	55	16	34	0	0	34	68	55	0	13
Gunnison River	Grand Junction	22	42	0	25	17	40	30	0	10	22	0	0	22
Uncompahgre River-Montrose Arroyo	Montrose	15	35	0	5	30	62	30	25	7	13	0	0	13
Dolores River Basin														
Dolores River	Dolores	36	69	0	0	69	148	0	126	22	36	0	0	36
Colorado River Basin														
Indian Wash & Colorado River	Grand Junction & Vicinity	30	58	0	5	53	103	46	30	27	40	0	0	40
Mill & Pack Creeks - Miscellaneous canyons	Moab	75	182	0	154	28	47	0	0	47	83	50	0	33
Subregion Totals		213	457	0	244	213	434	106	181	147	262	105	0	157

1/ Figures shown in Column 3 are from "Total" Column of Table 9 and are also shown in Column 3 of Table 9a.
2/ Figures in Column 4 are from Column 4 of Table 9a.
3/ Column 7 = Column 4 - Column 5 - Column 6.
4/ Column 11 = Column 8 - Column 9 - Column 10.
5/ Column 15 = Column 12 - Column 13 - Column 14.

TABLE 10

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 1966 to 1980 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Roaring Fork River Basin	0	0	0	0	150	1	0	0	0	0	0	0
Gunnison River Basin	0	0	0	0	2,000	3	0	0	0	0	0	0
Dolores River Basin	0	0	0	0	500	1	0	0	0	0	0	0
Colorado River Basin	3,000	0	250	5	1,280	0	420	6	100	39	0	0
Eagle River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Subregion Totals	3,000	0	250	5	3,930	5	420	6	100	39	0	0

1/ Costs of watershed treatment measures are not included.

TABLE 10a

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 1981 to 2000 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Roaring Fork River Basin	0	0	0	0	300	2	0	0	0	0	0	0
Gunnison River Basin	0	0	0	0	2,480	0	620	10	10	0	490	4
Dolores River Basin	400	0	100	4	1,180	3	20	1	120	30	0	0
Colorado River Basin	0	0	0	0	560	2	40	1	30	0	1,470	12
Eagle River Basin	0	0	0	0	320	0	80	2	0	0	0	0
Subregion Totals	400	0	100	4	4,840	7	760	14	160	30	1,960	16

1/ Costs of watershed treatment measures are not included.

TABLE 10b

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 2001 to 2020 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Roaring Fork River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Gunnison River Basin	0	0	0	0	1,100	0	190	6	30	0	1,170	10
Dolores River Basin	0	0	0	0	180	0	30	2	0	0	0	0
Colorado River Basin	0	0	0	0	0	0	0	0	20	0	980	9
Eagle River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Subregion Totals	0	0	0	0	1,280	0	220	8	50	0	2,150	19

1/ Costs of watershed treatment measures are not included.

TABLE 11

UPPER MAIN STEM SUBREGION OF THE UPPER COLORADO REGION

Flow Data at Selected Locations
(Flows in 1,000 cfs)

Study area/ stream	Location of stream gage	Non-damaging flow 1/	Date	Maximum flood of record: Flow: At time of occurrence	Maximum flood of record: Flow: Existing (1965) project conditions	Maximum flood of record: Flow: Future project conditions 2/: 1980	2000	2020	Flow of standard project flood: Existing (1965) project conditions	Flow of standard project flood: Future project conditions 2/: 1980	2000	2020	Flow of 100-year frequency flood: Existing (1965) project conditions	Flow of 100-year frequency flood: Future project conditions 2/: 1980	2000	2020
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Roaring Fork River Basin																
Roaring Fork	Glenwood Springs	10.0	1Jul57	19.0	19.0	14.0	14.0	14.0	45.0	35.0	35.0	35.0	24.0	18.0	18.0	18.0
Crystal River	Near Redstone	2.0	21Jun38	4.4	4.4	4.4	2.8	2.8	18.0	18.0	15.0	15.0	5.6	5.6	3.6	3.6
Gunnison River Basin																
Gunnison River	Near Grand Junction	15.0	23May20	35.7	35.7	22.0	22.0	22.0	56.0	46.0	46.0	46.0	46.0	24.5	24.5	24.5
Uncompahgre River	Colona	2.5	13Jun21	4.1	4.1	2.5	2.5	2.5	7.0	5.0	5.0	5.0	5.6	2.5	2.5	2.5
North Fork River	Somerset	3.5	4Jun57	7.9	7.0	7.0	7.0	7.0	10.5	10.5	10.5	10.5	8.5	8.5	8.5	8.5
Dolores River Basin																
Dolores River	Gateway	7.0	14May41	15.4	15.4	9.5	6.8	6.8	50.0	38.0	33.0	33.0	38.0	29.0	25.0	25.0
San Miguel River	At Naturita	4.0	15Apr42	7.1	7.1	7.1	3.5	3.5	30.0	30.0	16.0	16.0	14.5	14.5	7.6	7.6
Colorado River Basin																
Colorado River	Near Colorado-Utah State line	48.0	9Jun57	56.8	56.8	52.0	45.0	45.0	110.0	100.0	90.0	90.0	84.0	70.0	64.0	64.0
Mill Creek	Moab	3.0	21Aug53	5.1	5.1	3.5	3.5	3.5	27.0	15.0	15.0	15.0	16.0	6.0	6.0	6.0
Eagle River Basin																
Eagle River	Gypsum	5.0	11Jun52	6.6	6.6	6.6	6.6	6.6	38.0	38.0	38.0	38.0	12.0	12.0	12.0	12.0

1/ Under 1965 project conditions.
2/ Flows as modified by projects likely to be in a future flood control program by the years 1980, 2000, and 2020.

TABLE 1

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Historical Flood Data

Study area	Flood	Location/ flow (cfs)	Area inundated (1,000 acres)	Flood damages 1/ - ($1,000) Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utility	Public facilities	Total
1	2	3	4	5	6	7	8	9	10	11	12	13
Animas River Basin												
Animas River	5Oct11	Farmington 30,000	-	-	-	25	5	3	-	70	-	103
Animas River	29Jun27	Farmington 25,000	-	-	-	-	-	-	-	166	-	166
Hampton-Aztec Watershed	2Aug65	-	-	-	-	4	-	-	84	-	4	92
San Juan River Basin												
San Juan River	5Oct11	Shiprock 150,000	-	-	-	117	27	22	25	109	60	360
San Juan River	Jun-Jul57	Shiprock 30,900	-	-	-	2	5	1	3	-	24	35
Los Pinos River	12Aug64	La Boca 1,810	-	-	-	7	3	1	-	-	9	20

1/ Data based on prices and project and economic conditions at time of occurrence of flood.

TABLE 2

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Flood Damage 1/

Study area	Flood	Location/ flow (cfs)	Total damages - ($1,000) At time of flood 2/ Actual damage	At time of flood 2/ Damage without flood control projects	At time of flood 2/ Damage prevented by flood control projects 4/	1965 economic conditions & prices 3/ Damage with 1965 project conditions	1965 economic conditions & prices 3/ Damage without flood control projects	1965 economic conditions & prices 3/ Damage prevented by 1965 projects 5/
1	2	3	4	5	6	7	8	9
Animas River Basin								
Animas River	5Oct11	Farmington, New Mexico 30,000	103	103	0	2,500	2,500	0
Animas River	29Jun27	Farmington, New Mexico 25,000	166	166	0	1,850	1,850	0
Hampton-Aztec Watershed	2Aug65	-	92	92	0	92	92	0
San Juan River Basin								
San Juan River	5Oct11	Shiprock 150,000	360	360	0	1,850	3,400	1,550
San Juan River	Jun-Jul57	Shiprock 30,900	35	35	0	38	45	7
Los Pinos River	12Aug64	La Boca 1,810	20	20	0	20	20	0

1/ Maximum floods for which data are available.
2/ Data based on prices and project and economic conditions at time of occurrence of flood.
3/ Data based on recurrence of original flood.
4/ Column 6 = Column 5 - Column 4.
5/ Column 9 = Column 8 - Column 7.

BEST AVAILABLE COPY

TABLE 3

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Flood Damage for
the 100-Year Frequency Flood 1/
for Selected Streams

Study area/ stream	Area inundated (acres)	Flood damage 2/ - ($1,000) Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utilities	Public facilities	Total
1	2	3	4	5	6	7	8	9	10	11
Animas River Basin										
Animas River	5,000	0	0	130	60	35	280	275	350	1,130
San Juan River Basin										
San Juan River	16,000	15	10	150	62	100	280	418	439	1,474
Mancos River Basin										
Mancos River	3,500	0	0	25	20	12	35	15	60	167
Escalante River Basin										
Escalante River	4,000	5	0	20	25	36	48	0	70	204
Fremont (Dirty Devil) River Basin										
Fremont River	5,500	10	0	60	70	55	120	0	108	423
Piedra River Basin										
Piedra River	2,400	0	0	25	12	10	0	12	30	89

1/ See Table 11 for magnitude of 100-year flood at selected stations.
2/ Based on July 1965 prices, economic and project conditions.

TABLE 4

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage

Study area (principal stream)	Flood damage 1/ - ($1,000) Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utilities	Public facilities	Study area totals
1	2	3	4	5	6	7	8	9	10
Animas River Basin	4	1	46	4	10	61	38	52	216
Animas River	(0)	(0)	(29)	(2)	(3)	(18)	(18)	(25)	(95)
Florida River	(0)	(0)	(2)	(0)	(1)	(1)	(0)	(2)	(6)
Miscellaneous Streams	(4)	(1)	(15)	(2)	(6)	(42)	(20)	(25)	(115)
San Juan River Basin 2/	8	5	145	19	27	28	17	47	296
San Juan River	(2)	(1)	(10)	(4)	(10)	(15)	(11)	(20)	(73)
La Plata River	(0)	(0)	(5)	(4)	(2)	(1)	(1)	(5)	(18)
Miscellaneous Streams	(6)	(4)	(130)	(11)	(15)	(12)	(5)	(22)	(205)
Mancos River Basin	3	1	9	2	7	2	1	6	31
Mancos River	(0)	(0)	(3)	(1)	(3)	(2)	(1)	(3)	(13)
Miscellaneous Streams	(3)	(1)	(6)	(1)	(4)	(0)	(0)	(3)	(18)
Paria River Basin	1	0	10	2	4	2	0	6	25
Escalante River Basin	4	1	12	3	17	2	0	13	52
Escalante River	(1)	(0)	(6)	(2)	(12)	(2)	(0)	(5)	(28)
Miscellaneous Streams	(3)	(1)	(6)	(1)	(5)	(0)	(0)	(8)	(24)
Fremont (Dirty Devil) River Basin	6	1	15	10	25	5	0	16	78
Fremont River	(1)	(0)	(5)	(8)	(15)	(5)	(0)	(6)	(40)
Miscellaneous Streams	(5)	(1)	(10)	(2)	(10)	(0)	(0)	(10)	(38)
Piedra River Basin	2	1	5	1	5	0	1	5	20
Piedra River	(0)	(0)	(2)	(1)	(1)	(0)	(1)	(2)	(7)
Miscellaneous Streams	(2)	(1)	(3)	(0)	(4)	(0)	(0)	(3)	(13)
Subregion Totals	28	10	242	41	95	100	57	145	718

1/ Damages based on July 1965 prices, economic and project conditions.
2/ Includes data for the Canyon Largo Basin, Montezuma Creek Basin, Chinle Creek Basin, Chaco River Basin, and the San Juan River Basin.

TABLE 5

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Summary of Estimated Average Annual Flood Damage for Present and Future Conditions of Economic Development with Existing Flood Control Measures

Study area (principal stream)	Average annual flood damages 1/ - ($1,000)			
	1965 economic conditions 2/	1980 economic conditions	2000 economic conditions	2020 economic conditions
1	2	3	4	5
Animas River Basin	216	362	688	1,109
Animas River	(95)	(166)	(311)	(454)
Florida River	(6)	(11)	(17)	(25)
Miscellaneous streams	(115)	(185)	(360)	(630)
San Juan River Basin	296	451	803	1,248
San Juan River	(73)	(127)	(295)	(488)
La Plata River	(18)	(29)	(43)	(65)
Miscellaneous streams	(205)	(295)	(465)	(695)
Mancos River Basin	31	47	67	96
Mancos River	(13)	(20)	(31)	(44)
Miscellaneous streams	(18)	(27)	(36)	(52)
Paria River Basin	25	38	56	78
Escalante River Basin	52	78	110	153
Escalante River	(28)	(42)	(60)	(83)
Miscellaneous streams	(24)	(36)	(50)	(70)
Fremont (Dirty Devil) River Basin	78	125	183	255
Fremont River	(40)	(65)	(98)	(135)
Miscellaneous streams	(38)	(60)	(85)	(120)
Piedra River Basin	20	30	49	71
Piedra River	(7)	(11)	(16)	(25)
Miscellaneous streams	(13)	(19)	(33)	(46)
Subregion Totals	718	1,131	1,956	3,010

1/ Damages based on July 1965 prices and project conditions, and estimated economic conditions for the year shown.
2/ Figures in Column 2 are from Column 10, "Total", shown on Table 4.

TABLE 6

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Summary of Flood Control Capacity for Existing and Future Reservoirs

Study area	Flood control capacity 1/ - (1,000 ac-ft)				
	Existing projects (1965)	Projects 1966-1980	Projects 1981-2000	Projects 2001-2020	Total projects as of 2020
1	2	3	4	5	6
Animas River Basin	39	1	0	0	40
Florida River	(39)	(0)	(0)	(0)	(39)
Miscellaneous streams	(0)	(1)	(0)	(0)	(1)
San Juan River Basin	1,162	1	0	5	1,168
San Juan River	(1,036)	(0)	(0)	(0)	(1,036)
Miscellaneous streams	(126)	(1)	(0)	(5)	(132)
Paria River Basin	0	0	1	0	1
Escalante River Basin	0	0	2	0	2
Miscellaneous streams	(0)	(0)	(2)	(0)	(2)
Fremont (Dirty Devil) River Basin	0	1	11	21	33
Fremont River	(0)	(0)	(0)	(20)	(20)
Miscellaneous streams	(0)	(1)	(11)	(1)	(13)
Subregion Totals	1,201	3	14	26	1,244

1/ Maximum flood control capacity. Does not include surcharge storage.

TABLE 7

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Summary of Levee and Channel Flood Protection Projects
- Existing and Future -

Study area	Levee and channel projects: Existing projects (1965): Levees (miles)	Existing projects (1965): Channels (miles)	Projects 1966-1980: Levees (miles)	Projects 1966-1980: Channels (miles)	Projects 1981-2000: Levees (miles)	Projects 1981-2000: Channels (miles)	Projects 2001-2020: Levees (miles)	Projects 2001-2020: Channels (miles)	Total project as of 2020: Levees (miles)	Total project as of 2020: Channels (miles)
1	2	3	4	5	6	7	8	9	10	11
Animas River Basin										
Animas River	0	0	0	0	0	0.2	2.0	0	2.0	0.2
Junction Creek	0	0	0	0	0	1.6	0	0	0	1.6
Washes B & C (Farmington, New Mexico)	0	0	0	0	0	2.2	0	0	0	2.2
Subregion Totals	0	0	0	0	0	4.0	2.0	0	2.0	4.0

TABLE 8

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage and Damage Reduction
- Present and Future Economic Conditions -

Study area (principal stream)	Total damages - 1965 prices ($1,000): 1965 economic & project conditions 1/	1980 economic conditions: W/1965 program conditions 2/	1980: Reduction in damages due to 1980 flood control program 3/	1980: Residual damage w/1980 program 4/	2000 economic conditions: W/1980 program conditions	2000: Reduction in damages due to 2000 flood control program 3/	2000: Residual damage w/2000 program 5/	2020 economic conditions: W/2000 program conditions	2020: Reduction in damages due to 2020 flood control program 3/	2020: Residual damage w/2020 program 6/
1	2	3	4	5	6	7	8	9	10	11
Animas River Basin	216	362	18	344	663	330	333	498	185	313
Animas River	(95)	(166)	(0)	(166)	(311)	(40)	(271)	(395)	(167)	(228)
Florida River	(6)	(11)	(0)	(11)	(17)	(0)	(17)	(25)	(0)	(25)
Miscellaneous streams	(115)	(185)	(18)	(167)	(335)	(290)	(45)	(78)	(18)	(60)
San Juan River Basin	296	451	98	353	643	232	411	555	110	445
San Juan River	(73)	(127)	(0)	(127)	(295)	(147)	(148)	(185)	(15)	(170)
La Plata River	(18)	(29)	(0)	(29)	(43)	(0)	(43)	(65)	(0)	(65)
Miscellaneous streams	(205)	(295)	(98)	(197)	(305)	(85)	(220)	(305)	(95)	(210)
Mancos River Basin	31	47	0	47	67	0	67	96	20	76
Mancos River	(13)	(20)	(0)	(20)	(31)	(0)	(31)	(44)	(0)	(44)
Miscellaneous streams	(18)	(27)	(0)	(27)	(36)	(0)	(36)	(52)	(20)	(32)
Paria River Basin	25	38	8	30	42	5	37	52	0	52
Escalante River Basin	52	78	13	65	93	18	75	103	20	83
Escalante River	(28)	(42)	(5)	(37)	(53)	(0)	(53)	(72)	(10)	(62)
Miscellaneous streams	(24)	(36)	(8)	(28)	(40)	(18)	(22)	(31)	(10)	(21)
Fremont (Dirty Devil) River Basin	78	125	10	115	168	44	124	170	80	90
Fremont River	(40)	(65)	(0)	(65)	(98)	(0)	(98)	(135)	(65)	(70)
Miscellaneous streams	(38)	(60)	(10)	(50)	(70)	(44)	(26)	(35)	(15)	(20)
Piedra River Basin	20	30	6	24	38	0	38	55	8	47
Piedra River	(7)	(11)	(0)	(11)	(16)	(0)	(16)	(25)	(0)	(25)
Miscellaneous streams	(13)	(19)	(6)	(13)	(22)	(0)	(22)	(30)	(8)	(22)
Subregion Totals	718	1,131	153	978	1,714	629	1,085	1,529	423	1,106

1/ Figures shown in Column 2 are from "Total" Column of Table 4 and are also shown in Column 2 of Table 5.
2/ Figures in Column 3 are from Column 3 of Table 5.
3/ Includes structural and non-structural measures.
4/ Column 5 = Column 3 - Column 4.
5/ Column 8 = Column 6 - Column 7.
6/ Column 11 = Column 9 - Column 10.

TABLE 9

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage for Urban Areas with Significant Flood Problems

Study area/ stream	Damage center	Average annual flood damages ($1,000) 1/ Residential	Commercial	Industrial & utilities	Public facilities	Total
1	2	3	4	5	6	7
Animas River Basin						
Animas River-Goeglein Gulch-Junction Creek	Durango	9	7	5	16	37
San Juan River Basin						
Animas River-San Juan River-Washes B & C-Glade Arroyo	Farmington	30	13	16	28	87
San Juan River	Shiprock	3	1	6	6	16
Subregion Totals		42	21	27	50	140

1/ Damages based on July 1965 prices, economic and project conditions.

TABLE 9a

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Summary of Estimated Average Annual Flood Damage for Urban Areas with Significant Flood Problems
- Present and Future Conditions of Economic Development
with Existing Flood Control Measures -

Study area/ stream	Damage center	Average annual flood damages 1/ - ($1,000) 1965 economic conditions 2/	1980 economic conditions	2000 economic conditions	2020 economic conditions
1	2	3	4	5	6
Animas River Basin					
Animas River-Goeglein Gulch-Junction Creek	Durango	37	76	189	298
San Juan River Basin					
Animas River-San Juan River-Washes B & C-Glade Arroyo	Farmington	87	201	476	780
San Juan River	Shiprock	16	34	61	94
Subregion Totals		140	311	726	1,172

1/ Damages based on July 1965 prices and project conditions, and estimated economic conditions for the year shown.
2/ Figures in Column 3 are from Column 7, "Total", shown on Table 9.

TABLE 9b

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Average Annual Flood Damage and Damage Reduction
for Urban Areas with Significant Flood Problems
- Present and Future Economic Conditions -

Study area/ stream	Damage center	Total damages - 1965 prices ($1,000)												
		1965	1980 economic conditions				2000 economic conditions				2020 economic conditions			
		economic & project conditions 1/	W/1965 program 2/	Reduction due to 1980 program		Residual damage w/1980 program 3/	W/1980 program	Reduction due to 2000 program		Residual damage w/2000 program 4/	W/2000 program	Reduction due to 2020 program		Residual damage w/2020 program 5/
				Non-structural measures	Structural measures			Non-structural measures	Structural measures			Non-structural measures	Structural measures	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Animas River Basin														
Animas River-Goeglein Gulch-Junction Creek	Durango	37	76	0	0	76	189	0	120	69	104	60	0	44
San Juan River Basin														
Animas River-Glade Arroyo-Washes B & C-San Juan River	Farmington	87	201	0	0	201	476	110	210	156	225	0	107	118
San Juan River	Shiprock	16	34	0	0	34	61	37	0	24	34	0	0	34
Subregion Totals		140	311	0	0	311	726	147	330	249	363	60	107	196

1/ Figures shown in Column 3 are from "Total" Column of Table 9 and are also shown in Column 3 of Table 9a.
2/ Figures in Column 4 are from Column 4 of Table 9a.
3/ Column 7 = Column 4 - Column 5 - Column 6.
4/ Column 11 = Column 8 - Column 9 - Column 10.
5/ Column 15 = Column 12 - Column 13 - Column 14.

TABLE 10

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 1966 to 1980 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Animas River Basin	0	0	0	0	140	0	50	1	0	0	0	0
San Juan River Basin	0	0	0	0	750	0	250	3	0	0	0	0
Mancos River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Paria River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Escalante River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Fremont (Dirty Devil) River Basin	0	0	0	0	230	0	70	2	0	0	0	0
Piedra River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Subregion Totals	0	0	0	0	1,120	0	370	6	0	0	0	0

1/ Costs of watershed treatment measures are not included.

AD-A043 991 UPPER COLORADO REGION STATE-FEDERAL INTER-AGENCY GROUP F/G 8/6
UPPER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDY. APPENDIX I--ETC(U)
JUN 71

UNCLASSIFIED NL

2 OF 2
AD
A043991

END
DATE
FILMED
9 -77
DDC

TABLE 10a

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 1981 to 2000 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Animas River Basin	5,050	0	500	10	0	0	0	0	0	0	0	0
San Juan River Basin	0	0	0	0	0	0	0	0	160	23	2,530	21
Mancos River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Paria River Basin	0	0	0	0	80	0	20	1	0	0	0	0
Escalante River Basin	0	0	0	0	400	0	100	3	0	0	0	0
Fremont (Dirty Devil) River Basin	0	0	0	0	1,760	0	440	7	0	0	0	0
Piedra River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Subregion Totals	5,050	0	500	10	2,240	0	560	11	160	23	2,530	21

1/ Costs of watershed treatment measures are not included.

TABLE 10b

SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Estimated Costs of Future Flood Control Program
- 2001 to 2020 -
($1,000)

Study area	Levees & channels				Flood control reservoirs				Non-structural measures 1/			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs	Installation costs	Annual OM&R costs
1	2	3	4	5	6	7	8	9	10	11	12	13
Animas River Basin	1,100	0	400	6	0	0	0	0	30	0	1,170	10
San Juan River Basin	0	0	0	0	1,190	0	210	9	0	0	0	0
Mancos River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Paria River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Escalante River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Fremont (Dirty Devil) River Basin	0	0	0	0	1,170	10	30	1	0	0	0	0
Piedra River Basin	0	0	0	0	0	0	0	0	0	0	0	0
Subregion Totals	1,100	0	400	6	2,360	10	240	10	30	0	1,170	10

1/ Costs of watershed treatment measures are not included.

TABLE 11

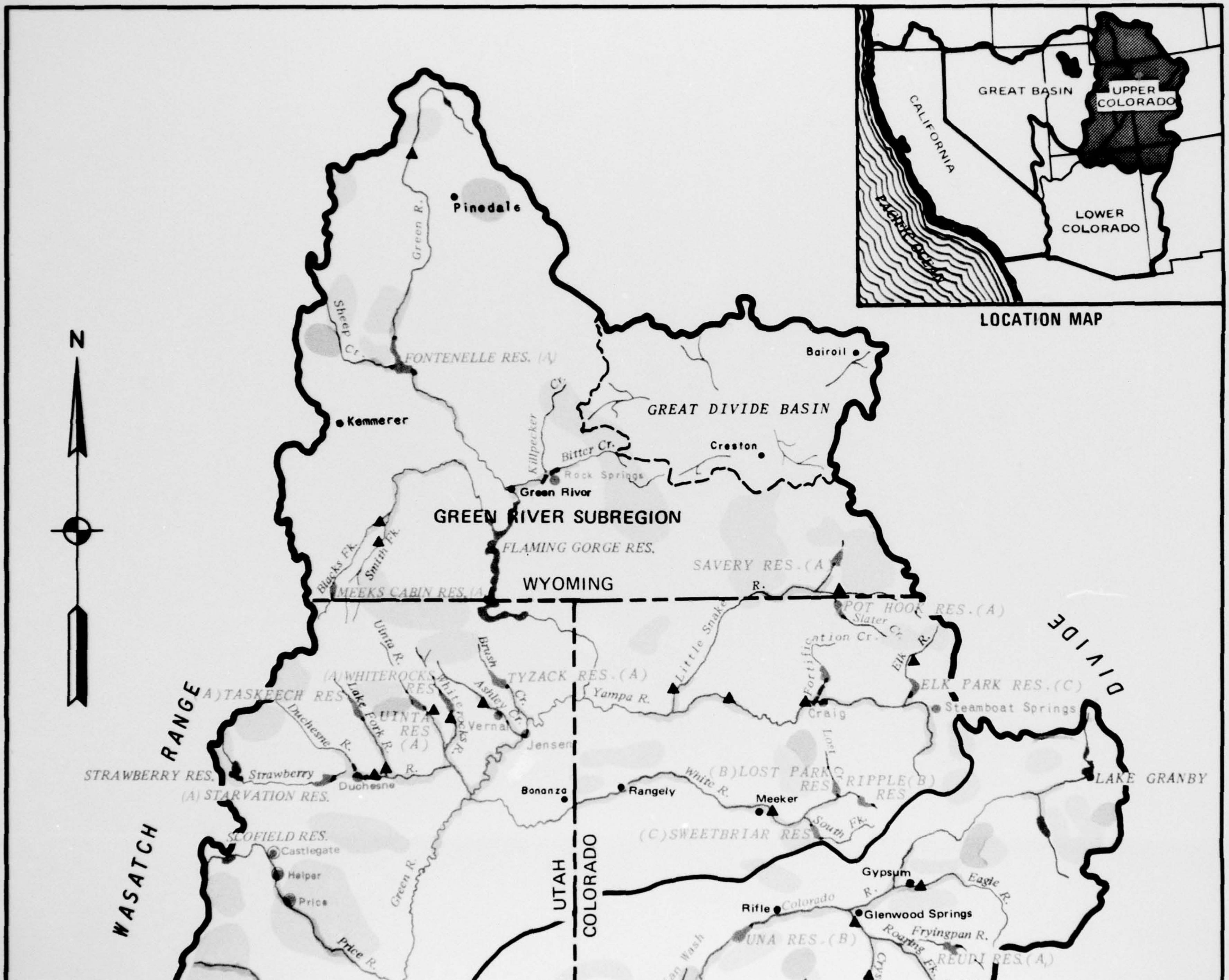
SAN JUAN-COLORADO SUBREGION OF THE UPPER COLORADO REGION

Flow Data at Selected Locations
(Flows in 1,000 cfs)

Study area/ stream	Location of stream gage	Non-damaging flow 1/	Maximum flood of record						Flow of standard project flood				Flow of 100-year frequency flood			
			Date	Flow												
				At time of occurrence	Existing (1965) project conditions	Future project conditions 2/			Existing (1965) project conditions	Future project conditions 2/			Existing (1965) project conditions	Future project conditions 2/		
						1980	2000	2020		1980	2000	2020		1980	2000	2020
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Escalante River Basin																
Escalante River	Escalante	2.0	Aug53	3.5	3.5	3.5	3.5	3.5	16.0	16.0	16.0	16.0	8.5	8.5	8.5	8.5
Fremont River Basin																
Fremont River	Bicknell 3/	3.0							18.0	18.0	18.0	12.0	10.0	10.0	10.0	3.5
Piedra River Basin																
Piedra River	Piedra	3.0	26Jul57	6.9	6.9	6.9	6.9	6.9	19.0	19.0	19.0	19.0	9.5	9.5	9.5	9.5
Animas River Basin																
Animas River	Farmington	10.0	29Jun27	25.0	25.0	25.0	25.0	25.0	75.0	75.0	75.0	75.0	27.0	27.0	27.0	27.0
Florida River	Durango	2.0	28Jun27	3.2	1.8	1.8	1.8	1.8	5.0	5.0	5.0	5.0	2.7	2.7	2.7	2.7
San Juan River Basin																
San Juan River	Farmington	17.0	29Jun27	68.0	21.0	21.0	21.0	21.0	70.0	70.0	70.0	70.0	21.0	21.0	21.0	21.0
La Plata River	Colorado-New Mexico State line	2.0	24Aug27	4.8	4.8	4.8	4.8	4.8	10.0	10.0	10.0	10.0	7.1	7.1	7.1	7.1
Mancos River Basin																
Mancos River	Tawaoc	2.0	14Oct41	5.3	5.3	5.3	5.3	5.3	12.0	12.0	12.0	12.0	9.0	9.0	9.0	9.0
Paria River Basin																
Paria River	Lees Ferry	3.5	5Oct25	16.1	16.1	16.1	16.1	16.1	52.0	52.0	52.0	52.0	25.0	25.0	25.0	25.0

1/ Under 1965 project conditions.
2/ Flows as modified by projects likely to be in a future flood control program by the years 1980, 2000, and 2020.
3/ Synthetic

BEST AVAILABLE COPY


LOCATION MAP
GREAT BASIN
UPPER COLORADO
LOWER COLORADO
CALIFORNIA
PACIFIC OCEAN
N
GREEN RIVER SUBREGION
GREAT DIVIDE BASIN
WYOMING
UTAH
COLORADO
WASATCH RANGE
DIVIDE
Pinedale
Kemmerer
Bairoil
Creston
Rock Springs
Green River
Green R.
Sheep Cr.
FONTENELLE RES. (A)
Killpecker Cr.
Bitter Cr.
Blacks Fk.
Smith Fk.
FLAMING GORGE RES.
MEEKS CABIN RES. (A)
SAVERY RES. (A)
Little Snake R.
POT HOOK RES. (A)
Slater Cr.
Fortification Cr.
Elk R.
ELK PARK RES. (C)
Steamboat Springs
Yampa R.
Craig
Uinta R.
(A) WHITEROCKS RES
Whiterocks R.
Brush Cr.
TYZACK RES. (A)
Ashley Cr.
Vernal
Jensen
(A) TASKEECH RES
Lake Fork R.
UINTA RES (A)
Duchesne R.
Duchesne
Strawberry
STRAWBERRY RES.
(A) STARVATION RES.
Bonanza
Rangely
White R.
Meeker
(B) LOST PARK RES
Lost Cr.
RIPPLE (B) RES
(C) SWEETBRIAR RES
South Fk.
LAKE GRANBY
SCOFIELD RES.
Castlegate
Helper
Price
Price R.
Green R.
Gypsum
Eagle R.
Rifle
Colorado R.
Glenwood Springs
Fryingpan R.
Roaring Fk.
UNA RES. (B)
REUDI RES. (A)
Aspen

WASATCH RANGE
CONTINENTAL
UPPER MAIN STEM SUBREGION
SAN JUAN – COLORADO SUBREGION
UTAH
COLORADO
ARIZONA
NEW MEXICO
STRAWBERRY RES.
(A) STARVATION RES.
(A) TASKEECH RES.
UINTA RES (A)
SCOFIELD RES.
FISH LAKE
CAINEVILLE RES. (C)
LAKE POWELL
LAKE GRANBY
(B) LOST PARK RES.
CRIPPLE (B) RES.
(C) SWEETBRIAR RES.
UNA RES. (B)
REUDI RES. (A)
PLACITA RES. (A)
PAONIA RES.
TAYLOR PARK RES.
MORROW POINT RES. (A)
BLUE MESA RES. (A)
RIDGWAY RES. (A)
(A) SALTADO RES.
McPHEE RES. (A)
VALLECITO RES.
LEMON RES.
NAVAJO RES.
TEFT SITE
Strawberry
Duchesne
Castlegate
Helper
Price
Green River
Bonanza
Jensen
Vernal
Rangely
Meeker
Craig
Steamboat Springs
Gypsum
Glenwood Springs
Rifle
Aspen
Fruita
Grand Junction
Delta
Montrose
Gunnison
Moab
Telluride
Silverton
Rico
Dolores
Durango
Aztec
Farmington
Shiprock
Bluff
Lees Ferry
Lee Ferry
Duchesne R.
Lake Fork R.
Green R.
Price R.
San Rafael R.
Fremont R.
Escalante R.
Paria R.
Colorado R.
Mill Cr.
Pack Cr.
Yampa R.
White R.
Lost Cr.
South Fk.
Eagle R.
Fryingpan R.
Roaring Fk.
Crystal R.
Muddy Cr.
North Fk.
Taylor R.
Gunnison R.
Indian Wash
Roat Cap W.
Uncompahgre R.
San Miguel R.
Dolores R.
Montezuma Cr.
San Juan R.
Mancos R.
La Plata R.
Wash B
Wash C
Animas R.
Junction Cr.
Florida
Los Pinos R.
Piedra R.
Canyon
Largo
Chaco R.
Chinle Cr.

LEGEND

- Existing Lake or Reservoir
- Existing Reservoir with Flood Control Storage
- Existing Watershed Treatment Area
- Future Reservoir with Flood Control Storage
- Future Watershed Treatment Area
- Future Levee and/or Channel Improvement
- (A)-1966-1980; (A_1)-In Operation by 1972; (B)-1981-2000; (C)-2001-2020 — Time Frame Designation
- Areas Subject to Flooding
- Principal Cities with Flood Problems
- Principal Stream Gaging Station
- Principal Cities with non-structural Flood Plain Management

UPPER COLORADO REGION

COMPREHENSIVE FRAMEWORK STUDY

FLOOD CONTROL PROGRAM

Scale in Miles

25 0 25 50 75 100

Plate 1

SUPPLEMENT A

Alternative Levels of Development

The projections of future flood damages and the associated flood control program for this study were formulated using the RI-OBERS level of future development. As alternatives to this level of development, average annual flood damage projections based upon baseline OBERS (1968) and the consumptive use of 6.5 and 8.16 million acre-feet of water per annum in the Upper Colorado Region were developed. These alternatives to the RI-OBERS level of development are briefly described in the following paragraphs. Population projections associated with these alternative levels of development are graphically depicted in the figure following page A-2.

Baseline OBERS (1968)

The Office of Business Economics, Department of Commerce and the Economic Research Service, Department of Agriculture (OBERS) projection series comprise a national-regional set of projections which equates national demand with supply and provides a first approach to consistent regional projections based on historic trends in interregional production relationships. The OBERS series provided projections of population, employment, and personal income at the regional and subregional levels for the target years 1980, 2000, and 2020, based upon the Series C population assumption. In addition, highly aggregated regional projections of such items as production and acreages for the agricultural and forestry sectors of the economy were also provided. Generally, baseline OBERS constitutes a somewhat lower projection series than RI-OBERS. Significant reductions in the level of output associated with agriculture, mining, manufacturing, and electric energy were projected under baseline OBERS as compared to the RI-OBERS level of development.

States' Alternative at 6.5 Million Acre-feet

The consumptive use of 6.5 million acre-feet of water per annum approximates the upper limit on land and water development in the Upper Colorado Region under terms of the Colorado River Compact, without an augmented water supply. The projected state distribution of water for consumptive use coincides with the percentage allotments under the Compact with adjustments in types of uses expressed by the respective states. The principal differences from the RI-OBERS projections are:

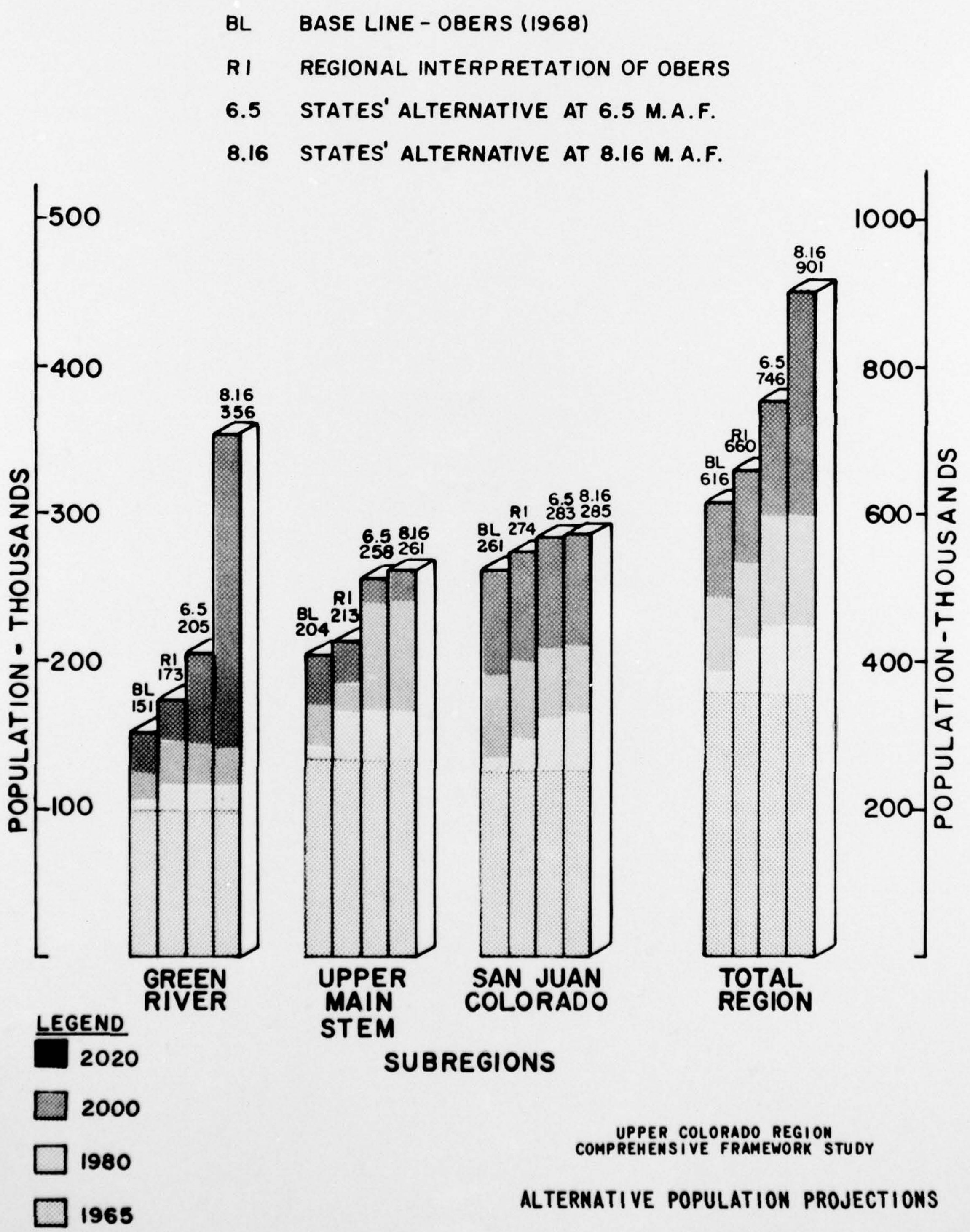
(1) the increased use of coal and water resources in the production of electric energy in Colorado, New Mexico, Utah, and Wyoming; (2) the addition of an oil shale industry in Utah and Colorado; and (3) the reduction of water use for irrigated agriculture.

States' Alternative at 8.16 Million Acre-feet

The consumptive use of 8.16 million acre-feet of water per annum in the Upper Colorado Region was determined to be the reasonable limit within which the states could afford the cost of water augmentation that would be required to develop related land resources. This plan of development assumes the Colorado River water supply would be firmed to meet the division of water by the Colorado River Compact. Generally, the changes from the RI-OBERS projected level of development included increases in the outputs projected for oil shale, coal by-products, potash, trona, electric energy, fish and wildlife, irrigated land, and exports of water outside the region.

Effect of Alternative Projections on RI-OBERS Flood Control Program

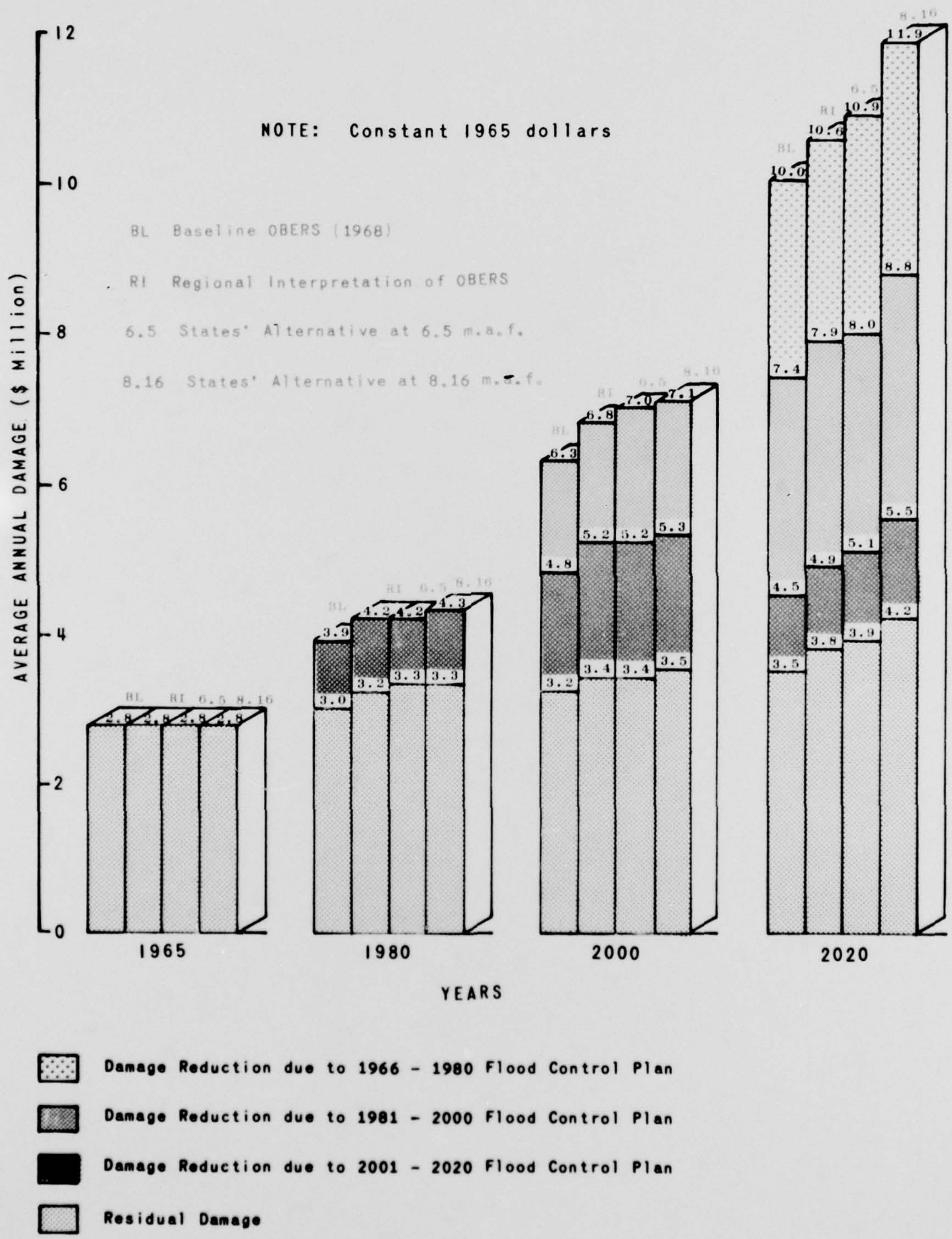
A comparison of the average annual flood damages under the various levels of future development is set forth in the figure following this page. Average annual flood damages for all the various levels of future development under present (1965) project conditions are estimated to reach or exceed $10 million by 2020. Residual average annual flood damages under the various levels of future development with the RI-OBERS flood control program are also presented in the figure. It can be seen from this figure that the differences in flood damages due to the different projections are small and no major adjustment would have to be made to the RI-OBERS flood control program to provide a reasonable degree of flood protection under the alternative levels of development. No specific analysis was made for the OBERS (1969) and Water Supply Available at Site alternatives but preliminary indications are that they would have little effect on the magnitude of future flood damages and the future flood control program in the region.



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

ALTERNATIVE POPULATION PROJECTIONS

APPENDIX IX



UPPER COLORADO REGION
COMPREHENSIVE FRAMEWORK STUDY

PROJECTED AVERAGE ANNUAL FLOOD DAMAGES

(1965 Price Level)

APPENDIX IX

SUPPLEMENT B

Glossary of Terms

Acre-foot. - A unit of volume of water equal to the volume of a prism one foot high with a base one acre in area.

Annual OM&R cost. - The value of goods and services needed to operate a constructed project and make repairs and replacements necessary to maintain the project in sound operating condition during its economic life.

Antecedent precipitation. - Precipitation that occurred prior to the particular event, condition, or time under consideration. Usually it applies to that prior precipitation which is still effective in modifying infiltration or runoff.

Average annual flood damages. - The weighted average of all flood damages that would be expected to occur yearly under specified economic conditions and development. Such damages are computed on the basis of the expectancy in any one year of the amounts of damage that would result from events throughout the full range of potential magnitude.

Bypass. - A channel carrying water around a part of and back to the main stream.

Channel. - A natural or artificial water course with definite bed and banks to confine and conduct continuously or periodically flowing water.

Detention structure (dam). - A structure constructed for the temporary storage of floodflows where the opening for release is of a fixed capacity and not manually operated.

Development factors. - Development factors are used in the projection of economic growth parameters (such as residential, commercial, agriculture, public facilities, etc.) to the various time frames. These factors are based on population projections, employment, per capita income, recreation demand, etc.

Flood control capacity. - That part of the gross reservoir capacity which, at the time under consideration, is reserved for the temporary storage of floodwaters. It can vary from zero to the entire capacity (exclusive of inactive storage) according to a predetermined schedule based upon such parameters as antecedent precipitation, reservoir inflow, potential snowmelt, or downstream channel capacities.

Flood forecasting. - Flood forecasts are primarily the responsibility of the National Weather Service, National Oceanic Atmospheric Administration and are used to predict flood stages and indicates areas subject to flooding.

Flood plain. - The relatively flat area adjacent to rivers or streams subject to overflow.

Flood plain, primary. - The streambed and that portion of the adjacent flood plain through which the main water flow is channelized during flood conditions.

Flood plain, secondary. - The fringe area of the flood plain within the boundaries of the selected flood which is subject to a less severe and less frequent inundation than found in the primary flood plain in times of flooding.

Flood plain information reports. - A factual report describing historical floods and the extent and depth of floods, velocities, and obstruction associated with two large future floods. These reports are prepared at the request of local public entities and indorsed by the appropriate state.

Flood frequency. - The average interval of time between floods equal to or greater than a specified discharge or stage. It is generally expressed in years.

Inactive storage. - That capacity below which a reservoir is not normally drawn, and which is provided for sedimentation, recreation, fish and wildlife, for purely aesthetic reasons, or for creation of a minimum controlled operational or power head in compliance with operating agreements or restrictions.

Installation costs. - The value of goods and services necessary for the establishment of the project, including initial project construction; land, easements, right-of-way, and water rights; capital outlays to relocate facilities or prevent damages; and all other expenditures for investigations and surveys, and designing, planning, and constructing a project after its authorization (excludes interest during construction). Also called project first costs.

Land treatment measures. - A tillage practice, a pattern of tillage or land use, or land or management facility improvements to alter runoff, reduce sediment production, improve use of drainage and irrigation facilities, or improve plant or animal production.

Levees. - A small continuous dike or ridge of earth for confining floodflows.

Peak flow. - The maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

Residual average annual flood damages. - Those flood damages which are not prevented by a flood control project. They may or may not be preventible by other flood control measures (including both structural and non-structural means).

Standard project flood. - A hypothetical flood representing the most critical flood runoff volume and peak discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic for the hydrologic region involved, excluding extremely rare combinations.

Watershed. - All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream.

Watershed projects. - Structural and non-structural measures to preserve or restore watersheds to good hydrologic conditions. These measures may include detention reservoirs, dikes, channels, contour trenches, terraces, furrows, gully plugs, revegetation, and possibly other practices to reduce flood peaks and sediment production.

SUPPLEMENT C

Bibliography

Water Resources Council, March 1968, Preliminary Report on Economic Projections for Selected Geographic Areas 1929 to 2020, Volume I, Washington, D. C.

U. S. Department of the Interior, Geological Survey, 1966, Reservoirs in the United States.

1966 Water-Supply Paper 1683, Part 9, Colorado River Basin Magnitude and Frequency of Floods in the United States.

1962, Geological Survey Circular 457, Floods in Utah, Magnitude and Frequency, Berwick, V. K.

1965, Geological Survey Professional Paper 441, Water Resources of the Upper Colorado River Basin - Technical Report, Iorns, W. V., C. H. Hembree and G. L. Oakland.

U. S. Department of the Interior, Bureau of Reclamation, Summary Report of the Commissioner, Project and Statistical Data.

U. S. Department of the Interior, Federal Water Pollution Control Administration, 1968, The Cost of Clean Water, Volume II.

U. S. Department of Agriculture, Agricultural Research Service, 1965, Causes of Variation in Runoff and Sediment Load from Small Drainage Basins in Western Colorado. Paper No. 14, in Miscellaneous Publication 970, Lusby, Gregg C.

1965, Land Use and Ecological Factors in Relation to Sediment Yields, Paper No. 11 in Miscellaneous Publication 970, Copeland, Otis, L. Jr.

1965, Sediment Reduction Through Watershed Rehabilitation, Paper No. 18 in Miscellaneous Publication 970, Noble, Edward L.

U. S. Department of Agriculture, U. S. Forest Service, 1934, Floods and Accelerated Erosion in Northern Utah, Miscellaneous Forestry Publication No. 196, Bailey, R. W., Forsling, C. L., and Becraft, R. J.

1937, Contour Trenches Control Floods and Erosion on Rangelands, Emergency Construction Work, Miscellaneous Forestry Publication No. 4, Bailey, R. W. and Croft, A. R.

1963, Sediment Reduction Through Watershed Rehabilitation, Intermountain Region, Ogden, Utah, Noble, Edward L.

1969, Forest Service Research in Erosion Control, Transactions, American Society of Agriculture Engineers, Volume 12, No. 1, Copeland, Otis L.

U. S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology.

1967, Updated Conservation Needs Inventory, for each of the following states--Arizona, Colorado, New Mexico, Utah, and Wyoming.

May 1963, Multiple-Purpose Watershed Projects, Under Public Law 566.

U. S. Department of Agriculture, Economic Research Service and Forest Service.

August 1967, Preliminary Projections of Economic Activity in the Agricultural, Forestry, and Related Economic Sectors of the United States and Its Water Resource Regions 1980, 2000, and 2020.

U. S. Department of Agriculture, Soil Conservation Service, and Colorado Water Conservation Board.

1969, Water and Related Land Resources, Yampa River Basin, Colorado and Wyoming.

1966, Water and Related Land Resources, White River Basin in Colorado.

1965, Water and Related Land Resources, Colorado River Basin in Colorado.

1962, Water and Related Land Resources, Gunnison River Basin, Colorado.

U. S. Department of Agriculture, Soil Conservation Service, Watershed Work Plan, February 1963, Roatcap Wash Watershed, Shavano Soil Conservation District and Uncompahgre Valley Water Users Association, Montrose County, Colorado.

September 1961, Indian Wash Watershed, Upper Grand Valley Soil Conservation District, Mesa County, City of Grand Junction, Colorado.

U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Water Supply Outlook for the Western United States, National Weather Service, Washington, D. C.

Daily River Stages, Compiled by National Weather Records Center, Environmental Data Service, Silver Spring, Maryland.

State of Colorado, Colorado State Engineer's Office, Inspection of Dams.

State of Utah, Utah State Engineer's Office, Report on Reservoirs in Utah by County.

State of Wyoming, Wyoming State Engineer's Office, Survey of Dams.

The University of New Mexico School of Law, January 1969, Natural Resources Journal, Volume 9, No. 1, The Willamette River, Flood Control or Flood Management, Raitt, Daryll D.

University of Arizona, 1967, Agricultural Experiment Station Report No. 248, Rainstorm Debris Floods, Croft, A. R.

American Water Resources Association, December 1969, Water Resources Bulletin, Volume 5, No. 4, Lake Eutrophication--A Natural Process, Greeson, Phillip E.

February 1970, Water Resources Bulletin, Volume 6, No. 1, Optimal Management of Flood Plains and Its Probable Form, Johnson, Reuben J.

Colmen, E. A., 1953, Vegetation and Watershed Management, The Ronald Press Company, New York.